The Sun Blade™ 1000 and 2000 Workstation Architecture

Technical White Paper

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The Sun Blade 1000 and 2000 workstations from Sun Microsystems, Inc. represent a significant step in multiprocessor desktop computing. By integrating new technologies into a workstation package, these workstations provide greater performance in graphics, I/O, and compute throughput, once again underscoring Sun's commitment to producing the most advanced, powerful, and affordable multiprocessing UNIX® workstations.

Workstation Computing Performance

The importance of performance and productivity in the technical workplace cannot be overstated. The future of a product — or even an entire organization — can rest on the talents of a few valuable technical professionals and the capabilities of their applications and systems. Extra testing and simulation of a design can make the difference between the success or failure of a product given today's narrow market windows. More importantly, powerful systems and visualization tools give scientists and forecasters precious minutes which can mean life or death to those in the path of a natural disaster.

At the same time, yesterday's trends are the driving issues of today's technical environment. High-speed networking brings very large datasets to technical users; large volumes of image and digital video data are now commonplace; demanding technical applications stress even the most robust systems. Organizations everywhere are working to shrink development time and engineering costs.

Fast processors are not enough — more than ever system architectures must be balanced to exploit the power today's CPUs can offer. Advanced computing platforms must provide *balanced performance* in many areas — memory access, system interconnects, I/O subsystems, graphics, and networking as well as CPU throughput — in order to avoid the performance bottlenecks that can destroy the productivity of an increasingly valuable workforce.

A Continued Commitment to Computing Excellence from Sun

Years ago, Sun engineers began to define a new computing architecture that would permit today's advanced applications to become a practical reality and not just a laboratory curiosity. In close consultation with customers and applications developers, they formulated a vision of computing practices and technologies that would define the standard for the industry over the next decade. With this commitment, they began to outline the requirements that would have to be met in order to complete their vision:

- *Desktop multiprocessing*

  Modern desktop systems must run power-hungry applications yet provide responsive windowing systems and high-performance interactive graphics while compute- and network-intensive jobs run in the background. As the demand for performance and scalability on the desktop grows, single-CPU architectures become increasingly expensive and impractical. Sun realized that desktop multiprocessing systems would provide an alternative, cost-effective way to obtain very high levels of aggregate compute performance.

- *Visual computing*

  The ability of high-performance graphics to communicate complex ideas is well established. Sun's team reasoned that next-generation platforms would require committed processor resources to support strong graphics integration, high-performance, 24-bit color, real-time video, 3D graphics, and imaging.

- *Network computing*

  To support the needs of workgroup interaction, Internet access, and advanced enterprise computing, Sun engineers knew that high-performance 100-Mbps Ethernet as well as efficient operation with even faster technologies like ATM and gigabit Ethernet would be required.

- *Scalability and binary compatibility*

  Sun understands the importance of scalable, binary-compatible systems. In order to remain flexible, systems architectures must be part of a powerful family of compatible products, with each member capable of accepting component upgrades and expansion to enhance performance and throughput. New platforms must be readily upgradable and must remain binary compatible with the thousands of applications already available for Sun systems.

- *Software interoperability and productivity*

  Even in highly technical environments, corporate standards and individual requirements dictate that users must have access to popular personal productivity applications, such as those that run on PCs running Microsoft Windows. In addition, object computing developments, such as Java™ technology, are vividly demonstrating their ability to shrink the cost and time required to develop and deploy new Internet-based applications. Sun knew that new platforms would have to address these requirements without compromise, either through native language support or additional adapter cards.

- *Workstation quality and technology*

  Workstations from Sun have long been associated with high levels of quality and reliability. Customers also know that with Sun, they can count on having access to the latest developments in systems and manufacturing technology.

- *Economy*

  One principal attribute of Sun's vision is that it defines a standard for all desktop systems. The technologies just mentioned — CPU performance, advanced graphics, high speed-networking, and advanced software technology — would need to be accessible and affordable for everyone.

The Continual Evolution of Desktop Multiprocessing

Able to tackle the complex needs of networked-based multimedia, object-oriented environments, and visual computing, Sun's first volley in creating a desktop platform to support the needs of a new generation of more demanding applications took form in the Sun Ultra™ 1 and Ultra 2 workstation systems.

Based on UltraSPARC™ processor technology, Ultra desktops quickly gained the attention of the industry as important new technical computing and multimedia platforms.

To address the needs of the largest commercial and technical computing tasks, Sun later introduced the Sun Enterprise™ server family. Sun Enterprise servers incorporate full symmetric multiprocessing (SMP) capabilities along with reliability, availability, and serviceability (RAS) features important to enterprise computing environments. Sun Enterprise server systems are available for the department, workgroup, and corporate datacenter, with configurations supporting from four to sixty-four high-performance UltraSPARC processors.

Understanding the continuing demand for performance and scalability in workstations, Sun unveiled a second generation of UltraSPARC processor-powered workstation systems with the Ultra 30, Ultra 60, Ultra 80, and Ultra 450 workstations. Today, Sun advances this trend with the introduction of the Sun Blade 1000 and 2000 workstations — the most powerful desktop systems available from Sun to date. The Sun Blade 1000 and 2000 workstations incorporate increased capacity and performance in nearly every dimension, demonstrating that Sun's vision for desktop computing continues unabated.

Powerful Desktop Multiprocessing Arrives

The Sun Blade 1000 and 2000 workstations represent high-performance dual-processing power in an affordable workstation package. Utilizing advanced manufacturing techniques and leveraging volume production of system components, the Sun Blade 1000 and 2000 workstations provide powerful, industry-leading performance, functionality, and economy. With several configuration available, users can choose the system that best matches their requirements or they can use the assemble-to-order option to create a system with a configuration of their choosing.

Sun Blade 1000/2000 workstations can be configured with one or two processors. The Sun Blade 1000 workstation comes configured with the 750-MHz UltraSPARC III module; however, it can be configured with 900-MHz UltraSPARC III modules or with the 900-MHz UltraSPARC III Cu processor modules. The Sun Blade 2000 workstation comes configured with either 900-MHz or 1050-MHz UltraSPARC III Cu processor modules.

All Sun Blade 1000/2000 workstations include 100-Mbps Fast Ethernet, a Fibre Channel arbitrated loop (FC-AL) disk interface, USB, IEEE 1394 (also known as FireWire®), and a 40 MB/second UltraSCSI interfaces. The amount of factory-configured memory varies from 512 MB to 8 GB.

Each system can support up to two 10000-rpm, FC-AL disk drives. The Sun Blade 1000 workstation comes configured with 36-GB drives. The Sun Blade 2000 workstation comes configured with 73-GB drives. The maximum internal storage supported is 146 GB.

A range of graphics accelerators are supported including Sun™ PGX64, Sun Creator3D, Sun Elite3D m6, Sun Expert3D-Lite, Sun Expert3D, and Sun XVR-1000 graphics. Multiple simultaneous monitor configurations are possible depending on the graphics accelerators selected.

Meeting the Needs of Today's Businesses

Designed for workstation "power users" who require high-performance multiprocessing capability and large amounts of expansion capacity, the Sun Blade 1000 and 2000 workstations easily meet the needs of users in a number of demanding disciplines:

- Electronic design automation (EDA)
- Mechanical design (MCAD/MCAE)
- Financial modeling
- Medical imaging
- Earth resources/geosciences
- Visualization and simulation
- Research and development

The Benefits of 64-bit Multiprocessing

Multiprocessing such as that found in the Sun Blade 1000 and 2000 workstations helps increase productivity by running tasks in parallel, speeding database queries, providing remote file service, and accelerating computationally intensive applications. Indeed, Sun's symmetric multiprocessing environment provides the flexibility to simply add or upgrade processors as needed, and helps ensure binary compatibility across systems. In addition, Sun provides the tools and related technologies need to enhance the effectiveness of multiprocessing systems.

Multiprocessing allows workstation users to reap tangible benefits by increasing performance in several ways. Often, these improvements can be realized immediately, without rewriting a single line of source code:

- The 64-bit multithreaded kernel of the Solaris™ Operating Environment enhances the inherent multitasking capability of the UNIX environment. Multiple tasks can be spawned to run simultaneously on multiple processors. I/O functions, backups, windows management, and database searches can all run in parallel, improving the overall system performance and throughput.
- In most UNIX environments, users run more than one application simultaneously. Multiprocessing enhances performance and throughput, because each application can run on a separate processor.
- The Solaris Operating Environment can split application system calls into separate processes, each running in parallel. Graphics, networking, compute, and I/O requests can be run on different processors at the same time.
- Forte™ Developer software suite toolkits and compilers automatically detect parallelism and spread program execution over many processors at run time.
- Multithreaded applications help enhance productivity by decreasing the time it takes to perform one job. Developers can assign multiple tasks in a single application to independent threads of execution, with the operating system automatically assigning each thread to an available processor.
- The full 64-bit environment provides outstanding support for customers who work with large data sets.

The Sun Blade 1000/2000 workstations are breakthrough offerings in UltraSPARC processor-based desktop systems from Sun Microsystems. Like their predecessors, the Sun Blade 1000/2000 workstations run the Solaris Operating Environment—Sun's benchmark implementation of System V Release 4 (SVR4) of the UNIX operating system—which provides binary compatibility with other SPARC processor-based Sun systems. With carefully balanced performance, multiprocessing, a full complement of advanced features, maximum upgradability, outstanding expandability, and excellent performance, the Sun Blade 1000/2000 workstations provide proof of Sun's desktop computing vision.

System Overview 2

All Sun systems use advanced materials, electronics, software, and fabrication technologies in their packaging, board design, subsystems, and components. This chapter briefly describes the Sun Blade 1000 and 2000 systems. More detailed discussions of the processor, interconnect, graphics, and I/O architectures can be found in subsequent chapters.

Features Summary

- *Processor*

  Up to two SPARC Version 9, 64-bit UltraSPARC III or UltraSPARC III Cu processors with 8 MB of external level-two cache. The UltraSPARC III and UltraSPARC III Cu processors provide very high integer and floating-point performance to address the needs of the most computationally demanding applications. With its exclusive VIS™ instruction set software, the UltraSPARC processor also greatly accelerates system graphics performance.

- *ECC-protected memory*

  512-MB to 8-GB using 3.3-V SDRAMs packaged in dual in-line memory modules (DIMMs). DIMMs are added in groups of four into the eight DIMM slots provided. 128-MB, 256-MB, 512-MB, and 1-GB DIMM capacities are supported.

- *Standard interfaces*

  The Sun Blade 1000/2000 workstations provide a number of high-performance and industry standard interfaces, including:
  - 100-Mbps IEEE 802.3 Fast Ethernet using a twisted pair interface, downward compatible with 10 Mbps Ethernet (autosense)
  - 12-Mbps universal serial bus (USB) Type A with four connectors
  - 400-Mbps, 6-pin IEEE 1394 interface
  - 1 Gbit/second Fibre Channel arbitrated loop (FC-AL)
  - Dual (internal and external) SCSI channels
  - Four general-purpose, 32- or 64-bit wide PCI expansion slots are provided that conform to the PCI V2.1 standard
  - Two 120-MHz UPA64S interface connectors support a range of graphics accelerators and allow for high speed operation with dual monitors
  - Two 384-Kbaud/460.8-Kbaud RS-232/RS-423 serial ports and a Centronics-compatible parallel port are provided
  - 16-bit, 8-KHz to 48-KHz sample rate audio with line-out, line-in, microphone-in, headphone-out, and internal wide-range speaker

- *Mass storage and removable media*

  Up to two internal 3.5-inch FC-AL drives (1.0-inch or 1.6-inch height) are provided. A 5.25-inch peripheral expansion bay is provided, for optional internal 1.6-inch high devices including: DVD-ROM, and 12- to 20-GB, 4-mm, and DDS-3 tape drive. A floppy drive is also available.

- *Graphics*

  The Sun Blade 1000/2000 workstations support a wide variety of Sun's graphics accelerators, given customers a choice form a low-cost, single-display, 2D graphics card to multi-display, accelerated texture-mapping, high-performance 3D graphics accelerators:
  - Sun PGX64 graphics
  - Sun Creator3D graphics
  - Sun Elite3D m6 graphics
  - Sun Expert3D-Lite graphics
  - Sun Expert3D graphics
  - Sun XVR-1000 graphics

These graphics choices support Sun's current 17-inch color, 21-inch color, 24-inch color, and 18-inch and 24-inch flat panel displays, as well as most of Sun's legacy monitors. (Note that Sun Elite3D m6 does not support the 24-inch HDTV monitor.)

- *Input devices*

  Keyboards include Sun Type 6 (USB), AT-101, or UNIX layout. Eighteen international layouts are available to support a worldwide customer base. An opto-mechanical three-button USB mouse is standard.

- *Software*

  Solaris 8 Operating Environment standard. OpenWindows™ environment and Motif windowing systems. CDE desktop environment. Sun's open systems distributed computing environment (ONC+™), NIS+, Sun's distributed computing file system (NFS), TCP/IP networking technologies provide maximum interoperability. A wide range of graphics protocols are available to support the large number of Solaris Operating Environment applications.

- *Reliability, availability, and serviceability (RAS) features*
  - Extensive power-on self test (POST)
  - ECC or parity on all major data buses, PCI bus parity protected
  - Software memory scrubbing
  - ECC on cache RAMs
  - Temperature-sensitive variable-speed fans
  - Internal thermal sensors control cooling
  - Thermal faults result in customer alerts and/or shutdowns to avoid component damage
  - SunVTS™ diagnostics tool can be run at scheduled times to periodically validate system functionality
  - Modular components include the motherboard, disks, memory DIMMs, graphics options, processor modules, and power supply
  - Common fasteners used throughout for easy servicing
  - No configuration jumpers
  - Real-time clock with battery backup on the motherboard
  - Non-volatile SEEROM memory for ID functions
  - Flash PROM for boot-time configuration. The PROM can be reprogrammed in the field from a CD-ROM or over a local-area network.

  - Meets all relevant and domestic agency safety, ergonomics, EMI, and environmental requirements.

- *Power management*

  An innovative approach to power management enables Sun Blade 1000 and 2000 systems to remain network-aware — even in low-power mode.

The UltraSPARC III and UltraSPARC III Cu Processors

Sun Blade 1000 and 2000 workstations are powered by 64-bit UltraSPARC III or UltraSPARC III Cu processors with 8-MB level-two cache. Binary compatible with all Sun SPARC processor-based systems, the UltraSPARC III and UltraSPARC III Cu processors provide very high integer and floating-point performance to address the needs of the most computationally demanding applications.

The UltraSPARC III processor is standard in the Sun Blade 1000 system. The UltraSPARC III Cu processor is available in the Sun Blade 1000 system only as an X-option, and is standard in the Sun Blade 2000 systems.

Capable of 64-bit data and addressing, UltraSPARC III and UltraSPARC III Cu processors have a number of important features to improve operating system and application performance:

- Larger cache, improved branch prediction, lower cache latency, and higher clock rates double the performance of the UltraSPARC III and UltraSPARC III Cu processors
- 6-way superscalar issue, no-stall 14-stage pipeline
- Enhanced VIS instruction set with three new instructions for high-performance on multimedia and networking applications
- High-efficiency trap management
- 16 K-entry branch prediction array
- 16 million transistor design (including cache) implemented using 0.25 micron, 6-layer metal CMOS technology operating at 1.8 volts. Packaged using a 1200-pin (800 signal) ceramic land gate array (LGA).
- 4-way associative on-chip 64-KB data and 32-KB instruction cache, with up to 8 MB of external level-two cache through integrated memory controller
- Support for data prefetch and multiple outstanding memory requests
- Integrated DRAM controller with support for up to 8 GB of memory can transfer data at up to 2.4 GB/second per processor

- Interface to the 128-bit Sun Fireplane interconnect supports peak data rates of nearly 4.8 GB/second

The Sun Fireplane Interconnect

In recent years, processor technology has moved so quickly that memory systems and interconnects have been hard-pressed to keep up. As a result, many designs fail to deliver the data bandwidth that modern processors demand. With the Sun Fireplane interconnect, Sun Microsystems continues the tradition of providing superior memory and I/O bandwidth on its desktop systems.

Features of the Sun Fireplane interconnect include:

- Fast 150-MHz operating frequency offers greatly increased performance over previous designs
- Low-latency memory access
- Completely separate address/control and data paths for flexible implementation
- Out-of-order transaction processing allows multiple “in-flight” transactions on the bus at one time
- High throughput paths to memory clocked at 150 MHz (576-bit wide paths including ECC)
- Integrated support for multiprocessor configurations

Mass Storage and Removable Media

Fibre Channel Arbitrated Loop (FC-AL) Internal Drives

Sun has been an early and aggressive adopter of Fibre Channel arbitrated loop (FC-AL) technology, in its higher-end systems and disk array technology with thousands of terabytes in the hands of Sun customers.

Sun Blade 1000 and 2000 systems mark the debut of this exciting high-bandwidth (1 Gb/second) technology in desktop systems, offering considerable performance advantages and deployment flexibility over slower interfaces. Only FC-AL disk drives are supported for internal mass storage in Sun Blade 1000 and 2000 systems.

Two internal 3.5-inch FC-AL drives (1.0-inch or 1.6-inch height) are provided. All systems support 18-, 36-, and 73-GB drives for a total capacity of 146-GB internal storage; however the Sun Blade 1000 configurations come with 18 GB or 36 GB capacities, and the Sun Blade 2000 workstation is configured with 73-GB drives.

Removable Media and Expansion Bays

Three removable media bays are provided with the Sun Blade 1000/20000 systems.

- A 5.25-inch peripheral expansion bay is provided, for optional internal 1.6-inch high devices including: a CD-ROM, a DVD-ROM, or a 12- to 20-GB, 4-mm, DDS-3 tape drive
- One 3.5-inch peripheral bay holds the standard smart card adapter.
- A third bay accommodates an additional 5.25-inch or 3.5-inch front access device.

Other Mass Media

Sun Blade 1000 and 2000 systems support external 8-mm or 4-mm tape drives, 4-mm tape autoloaders, 20- to 70-GB DLT tape drives, numerous Sun StorEdge™ disk storage options, and tape library systems through external UltraSCSI and FC-AL interfaces.

Sun Blade 1000 and 2000 systems also support USB mass storage and USB removable mass storage devices, such as the Iomega Zip and Jaz drives.

PCI Expansion Bus

In addition to its commitment to expand the capacity and performance of all of its systems, Sun is continually looking for ways to increase openness and standards compliance. Choosing PCI as the expansion bus for the Sun Blade 1000/2000 workstations leverages the strengths of this industry standard:

- *PCI is an open, architecture-independent bus*

  Because PCI is open and shipping in volume, it has been quickly adopted by both consumers and producers of computer hardware. As a result, significant numbers of platform-independent PCI solutions are available for integration into the Sun Blade 1000/2000 workstations.

- *PCI is fast*

  The PCI bus architecture is designed to provide high performance, with its I/O performance a key differentiator from other bus architectures. Running at 33-MHz and 66-MHz, PCI offers configurations that meet a variety of developer and user needs.

- *PCI is standardized*

  PCI is a standard bus architecture that has been adopted by the volume personal computer industry. Because of its wide acceptance, PCI promises that compliant adapter cards will be available from more sources than ever before.

Not content to simply repeat what others have done with the technology, Sun has innovated with PCI, providing:

- Compatibility with the PCI v2.1 standard
- Two independent buses to four general-purpose PCI expansion slots for sustained performance
- One dedicated slot is capable of both 66- and 33-MHz operation, while the remaining three slots are clocked at 33 MHz.

Graphics

Sun has long appreciated the importance of high-performance graphics in the technical workstation market. Sun Blade 1000 and 2000 systems continue this trend by offering a wide range of graphics options. Both PCI-based accelerators and existing accelerators based on the UPA64S interconnect are supported.

Sun PGX64 Graphics

The Sun PGX64 frame buffer is Sun's entry-level, high-resolution 8- and 24-bit color PCI graphics card — supporting all Sun PCI I/O based platforms. The Sun PGX64 frame buffer can be added to standard Sun Blade 2000 systems for those who need a low-cost, multiple-display configuration.

Sun PGX64 graphics is an ideal solution for those who need fast X Windows performance or need to display 24-bit and 8-bit 2D graphics at full speed. With 8 MB of SGRAM, the Sun PGX64 frame buffer is capable of providing 8-bit and 24-bit displays at resolutions up to 1920 x 1080 and up to 1920 x 1200 resolution in pseudo color (8-bit color) mode. Sun PGX64 graphics is backwards compatible with the feature set of its predecessors, the PGX24™ and PGX32™ frame buffers.

Sun PGX64 graphics eliminates colormap flashing when running both 8-bit and 24-bit applications, and allows legacy 8-bit graphics applications to run simultaneously with the latest 24-bit software. Sun PGX64 frame buffer also allows an 8-bit window on top of the 24-bit visuals without damaging the underlying window, resulting in a better user experience and smooth manipulation of graphics elements.

Sun Creator3D Graphics

The Sun Creator3D graphics accelerator adds considerable enhancements for 2D applications such as imaging, video, multimedia and 2D graphics applications along with fast 8- and 24-bit window system performance. In addition, Sun Creator3D graphics adds significant 3D functionality:

- Double-buffering and Z-buffering, along with accelerated quad and triangle rendering and Z-buffer support accelerates 3D solids and animation applications.

- 96-bit planes, including full 24-bit double buffer planes required for smooth animation, an 8-bit pseudocolor overlay, and 4-bit stencil. A 28-bit Z-buffer enables hardware assisted hidden surface removal for dynamic rendering of 3D objects.
- Full compatibility with (single-buffered) Creator accelerators with no compromise to window system, 2D graphics, imaging or video performance
- Transparent acceleration for applications written in standard 3D APIs, such as Java 3D™ and OpenGL® APIs.

Up to two Sun Creator3D graphics accelerators can be configured for dual-headed operation via the UPA64S ports of the Sun Blade 1000 and 2000 workstations.

Sun Elite3D m6 Graphics

Sun Blade 1000 and 2000 systems support the Sun Elite3D m6 graphics accelerator, with its significantly higher levels of performance and functionality:

- Standard 24-bit color, 1280 x 1024 resolution, MPEG playback acceleration at 30+ frames per second, greater than 4.7 million 2D vectors per second, greater than 8.2 million 3D vectors per second, over 5.9 million triangles per second, and on-board image acceleration functions.
- 88-bit planes, including full 24-bit double-buffer planes for smooth animation. A 28-bit Z-buffer is included to provide support for hidden surface removal and dynamic rendering of 3D objects.
- Support for a wide array of important graphics functions, including Bresenham lines; polygons; fonts; accelerated dots, lines, triangles, and quadrilaterals; antialiasing of dots and lines; Gouraud shaded triangles; specular lighting; hardware per-pixel depth cueing; transparency; texture map support; compressed 3D geometry decompression; viewport clipping; flexible blending operations; and a full set of Boolean operations.
- Sun / Mitsubishi developed 3D-RAM to improve 3D graphics rendering performance
- Design that exploits the high floating-point performance and VIS instruction set of the UltraSPARC III and UltraSPARC III Cu processors

- High-speed RAMDAC that can display 8-bit and 24-bit images simultaneously. Programmable video timing generator for multiple resolution support
- Complete compatibility with existing Sun graphics APIs, including X11, Java 3D, OpenGL, and XIL™ APIs

In line with its philosophy of uninhibited expansion potential, the Sun Blade 1000 and 2000 workstations have two UPA64S slots for “dual-headed” (two monitor) Sun Elite3D m6 graphics operation.

Sun Expert3D and Sun Expert3D-Lite Graphics

The Sun Expert3D and Sun Expert3D-Lite graphics accelerators share the same basic architecture and feature set but offer different cost and performance characteristics.

The Sun Expert3D-Lite graphics is ideal for 3D applications that require the 3D graphics performance of Sun Elite3D graphics but also need accelerated texture mapping support. Sun Expert3D-Lite graphics provide an affordable, high-performance graphics solution that features hardware-based texture mapping acceleration through 16 MB of dedicated texture memory.

Sun Expert3D graphics is Sun’s high-end graphics platform serving demanding applications in geothermal, high-end MCAD, digital content creation, visualization, and simulation, where hardware-based texture mapping is essential. Sun Expert3D graphics provides outstanding 3D graphics performance and support for larger texture storage. Features of Sun Expert3D graphics include:

- 128-MB total on-board memory with 64 MB for accelerated texture-mapping performance for acceleration of complex 2D and 3D textures
- True-color, 3D double-buffering, and Z-buffering at very high resolutions for large screen HDTV monitor support as well as stereo-mode graphics for enhanced realism at high resolutions
- On-board geometry accelerator delivers up to 6-million triangles per second with up to 3.2 Gigaflops of floating-point performance
- On-board rasterization engine performs triangle setup, texture processing, and pixel operations at up to 143 Mpixels per second fill rate

- Compatibility with Sun's graphics APIs including Sun™ OpenGL® for Solaris™ version 1.1.2 (or later) and Java 3D API

Sun XVR-1000 Graphics

The Sun XVR-1000 graphics accelerator is the newest member of Sun's graphics accelerator family. This graphics accelerator is an ideal solution for customers who need industry-leading workstation image quality. It is also an excellent solution for customer applications that can benefit from its large texture memory, 30-bit color precision, or its fast and flexible multi-head output options.

The Sun XVR-1000 graphics accelerator is the first product in a family of products using an entirely new scalable graphics architecture. The modular design of the architecture provides a growth path, allowing for even higher levels of performance and capabilities in future products.

Sun XVR-1000 graphics accelerator is available as an X-option supported in Sun's Ultra 60, Ultra 80, Sun Blade 1000, and Sun Blade 2000 workstations. In addition, it is a component of a few Sun Blade 2000 workstation factory-orderable configurations.

Networking and Peripheral Support

All Sun Blade 1000 and 2000 models provide standard 100-Mbps Fast Ethernet, which can autosense and accommodate 10-Mbps operation. In addition, a wide range of serial I/O options are supported, bringing new capabilities and levels of performance to desktop workstations:

- *USB*

  Universal serial bus (USB) was developed by the PC industry to provide a low-cost solution and a single connector type for attaching peripheral devices such as keyboards, mice, printers, and removal storage devices (such as the Iomega Zip and Jaz drives).

  The USB Type A connectors provide a maximum of 12-Mbps operation, hot-plug capabilities, and extension through USB hubs.Four USB connections are provided with these workstations.

- *IEEE 1394*

  IEEE 1394 — also known as FireWire — has emerged as a new standard for medium-speed devices such as digital cameras and digital video cameras. IEEE 1394 provides an isochronous service that guarantees latency along with providing the needed 400 Mb/second bandwidth for transferring large images and other multimedia data. Two IEEE 1394 connectors are provided.

- *External Fibre Channel arbitrated loop (FC-AL) connector*

  Sun Blade 1000 and 2000 systems mark the debut of using the FC-AL technology for the connection of external storage devices. This connection expands the number of mass storage devices (such as Sun StorEdge disk array options that are supported. In addition it offers considerable performance advantages and deployment flexibility over slower SCSI interfaces.

- *SCSI*

  Sun Blade 1000 and 2000 systems continue to provide an external 40 MB/second UltraSCSI (Fast-20) peripheral interface channel for support of legacy external SCSI devices. UltraSCSI is completely compatible with earlier Fast (10 MB/second) and standard 8-bit (5 MB/second) SCSI peripherals. A standard external 68-pin connector is provided. A second internal (narrow) SCSI port is provided for internal removable SCSI devices such as CD-ROMs and DVD-ROMs.

Enclosure and Power

Flexible Enclosure

Like every other aspect of the Sun Blade 1000 and 2000 workstation design, the system enclosure is designed to accommodate uncompromised expansion. To provide the most expansion potential in a personal system, Sun Blade 1000 and 2000 workstations employ a “tower” enclosure that can be placed upright at the deskside or on the desktop next to the monitor. In addition to affording room for two modular processors, four full-sized PCI expansion cards, and two (UPA64S) graphics frame buffers, the tower accommodates flexible internal and external peripheral expansion options:

- Two 1.6-inch or 1.0-inch FC-AL disk drives

- Three front-access bays accommodate a variety of removable media devices: One 5.25-inch internal bay supports optional DVD-ROM or 12 to 20 GB, 4-mm DDS-3 tape drive
- A second 5.25-inch bay accommodates optional 5.25-inch or 3.5-inch devices such as a floppy drive, or other removable media devices capable of interfacing to a PCI I/O slot
- A third 3.5-inch bay holds the standard smart card reader

The back panel of the Sun Blade 1000 and 2000 workstations (Figure 3-5) includes a number of other standard input/output connectors for external connection to networks, SCSI, parallel and serial peripherals, and audio equipment. For instance external Sun StorEdge array subsystems, tape options, and tape library systems can be connected through external UltraSCSI and FC-AL connectors for high reliability storage and backup needs. The Sun Blade 1000 and 2000 system enclosure is pictured in Figure 2-1.

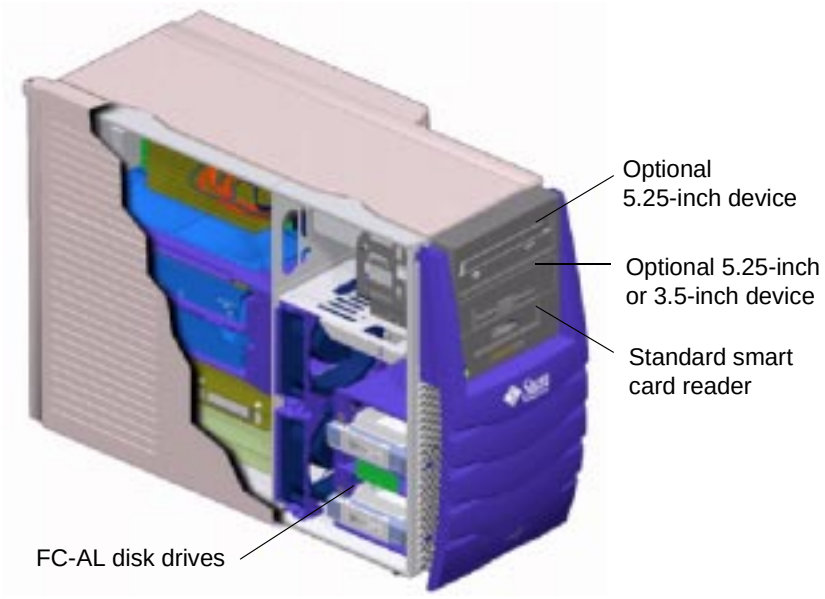

Figure 2-1 The Sun Blade 1000 and 2000 enclosure accommodates peripheral expansion through two 1.6-inch drive bays for FC-AL disk drives and three expansion bays: a half-height 5.25-inch bay, a 5.25-inch bay that accommodates either a 5.25-inch or 3.5-inch front access device, and a half-height 3.5-inch bay for the standard smart card reader

Advanced Power Management

The Sun Blade 1000 and 2000 workstations come equipped with a single 670 W power supply providing the power needed for internal expansion options. With the Sun Blade 1000 and 2000 workstations, Sun has gone beyond the need for environmentally sensitive construction and provides an innovative approach to power management. For instance, Sun Blade 1000 and 2000 systems remain network-aware, even when running in low-power mode. When the system senses activity it can leave low-power mode in less than 1 second.

The Sun Blade 1000 and 2000 Architecture 3

The Sun Blade 1000 and 2000 system architecture was designed to provide high-performance multiprocessing power, scalability, reliability, and flexibility in a balanced package that does not compromise economy. The very high levels of integration achieved through the use of application-specific integrated circuits (ASICs) have resulted in a greatly reduced part count, high reliability, and low cost, without compromising access to a full complement of expansion options through high-performance, standardized interfaces.

The following pages describe the Sun Blade 1000 and 2000 system architecture in detail, beginning with a system block diagram (Figure 3-1). The UltraSPARC III and UltraSPARC III Cu microprocessors are covered in depth since they are tightly integrated into the Sun Blade 1000 and 2000 system architecture. In addition, the memory subsystem, Sun Fireplane interconnect architecture, PCI bus, significant ASICs, and standard peripherals are described. Because Sun Blade 1000 and 2000 systems have some very special graphics capabilities, *Chapter 4* describes Sun Blade 1000 and 2000 workstation graphics options.

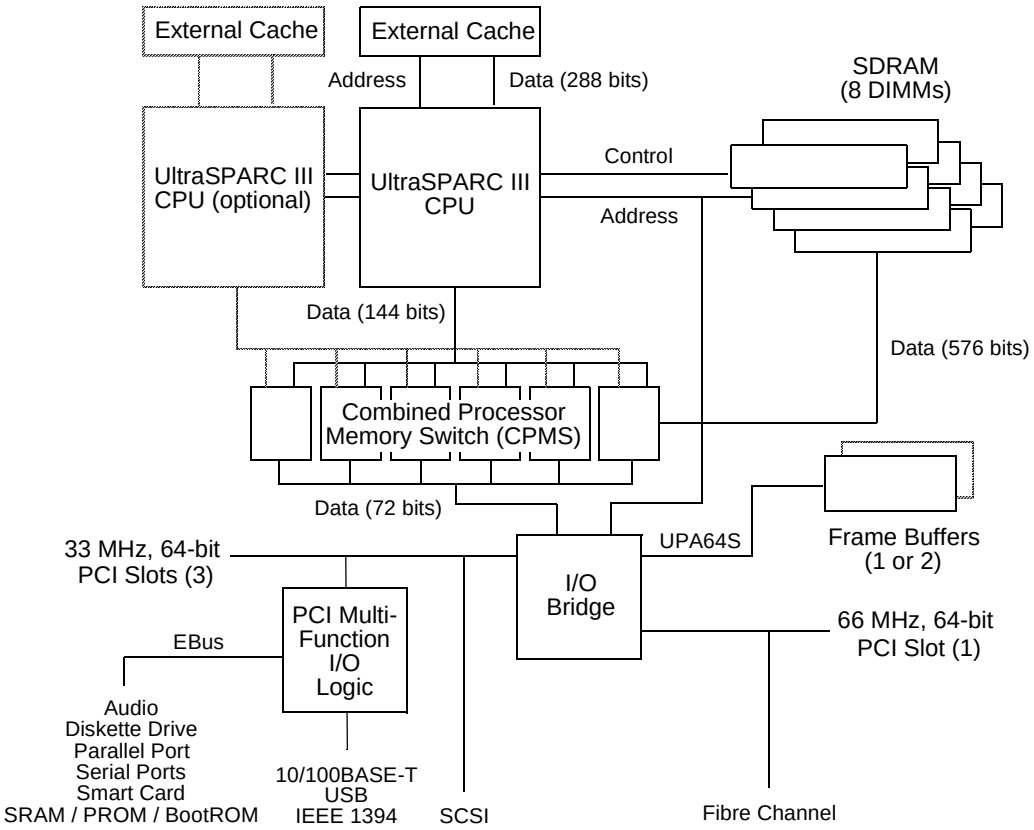

Figure 3-1 High-level architecture of the Sun Blade 1000 and 2000 workstations

The UltraSPARC III and UltraSPARC III Cu Microprocessors

The Version 9 Architecture

The SPARC architecture has been implemented in processors used in a range of computers from laptops to supercomputers. SPARC International member companies have implemented numerous compatible microprocessors since the SPARC platform was first announced — more than any other reduced instruction set computing (RISC) microprocessor family. As a result, the SPARC architecture today boasts the support of thousands of compatible software and

hardware products. SPARC Version 9 maintains upward binary compatibility for application software developed for previous SPARC architecture implementations, including microSPARC™, TurboSPARC, SuperSPARC™, and previous versions of UltraSPARC processors.

SPARC-V9 processors represent a significant advance for the industry. They provide 64-bit data and addressing, fault tolerance features, fast context switching, support for advanced compiler optimizations, efficient design for superscalar processors, and a clean structure for emerging operating systems. All of this has been accomplished with full binary compatibility for existing SPARC processor-based application programs.

UltraSPARC III and UltraSPARC III Cu Processors

The UltraSPARC III and UltraSPARC III Cu processors are part of a third generation of UltraSPARC pipeline-based products. In addition to using a new process technology, the UltraSPARC III and UltraSPARC III Cu processors provide higher clock frequencies, reduced on-chip latencies, support for greater amounts of level-one and level-two cache, and an integrated external memory controller. Other features includes support for very large multiprocessor systems, as well as features designed to support increased reliability through enhanced error detection and correction. At the same time, it provides software compatibility with existing UltraSPARC processor-based systems.

The UltraSPARC III and UltraSPARC III Cu processors supports both 2D and 3D graphics as well as image processing, video compression and decompression, and video effects through an enhanced VIS instruction set. VIS provides high levels of multimedia performance, including real-time H.261 video compression/decompression and two streams of MPEG-2 decompression at full broadcast quality without the need for additional hardware.

Key Features of the UltraSPARC III and UltraSPARC III Cu Processors

The newest members of Sun's family of SPARC CPUs, the UltraSPARC III and UltraSPARC III Cu processors are the most sophisticated of the SPARC family of processors to date. Designed for use in uniprocessor and multiprocessor systems, the UltraSPARC III and UltraSPARC III Cu processors offer the following key features:

- SPARC Version 9 architecture compliant
- Binary compatible with all existing SPARC applications
- Enhanced VIS instruction set to support advanced multimedia capabilities
- Multiprocessing support for over 1000 processors
- Six-way superscalar issue design incorporating seven execution units — four integer execution pipelines (IEUs) and three floating-point execution units (FPUs).
- Selectable little- or big-endian byte ordering
- 64-bit address pointers that enjoy transparent compatibility with 32-bit addressing
- 64-KB, 4-way set-associative data cache
- 32-KB, 4-way set-associative instruction cache steers up to four instructions/cycle to six execution pipes
- Integrated second-level cache controller supports 8 MB caches. Sustained throughput of 1 load per cycle and 3.2 GB/second processor-cache bandwidth
- 2.4 GB/second processor-memory bandwidth
- 16 million transistor design (including cache) implemented using 0.25 micron, 6-layer metal CMOS technology operating at 1.7 volts. Packaged using a 1200-pin (800 signal) ceramic land gate array (LGA)
- On-chip power management

UltraSPARC III and UltraSPARC III Cu Comparison

Sun has made significant reliability and performance improvements to the UltraSPARC III module and released it under the name the UltraSPARC III Cu processor. Starting at a speed of 900 MHz, this updated processor includes all the features of its predecessor, plus a few additions that result in world-class benchmarks.

- Prefetch is enabled in the UltraSPARC III Cu modules. This feature significantly improves floating point and integer arithmetic performance (up to 15 percent).
- The performance gain also comes from a combination of support for the two-way, set-associate external cache and a larger cache table.

Specific applications in the oil and gas, MCAE/MCAD, and EDA markets have seen significant performance boosts over the 900-MHz UltraSPARC III CPU modules that do not have prefetch enabled.

Also in the UltraSPARC III Cu processor, Sun has improved RAS significantly by adding more ECC/parity protection to on-chip SRAM structures. With higher density chip and lower core voltage, SRAM cells become more vulnerable to bit flips from cosmic rays disturbance. In this new processor, single-bit errors on majority of internal SRAMs are more readily detected and recovered from. For fault tolerant systems, the UltraSPARC III Cu processor now has a new SRAM initialization (zeroing out all on-chip SRAM structures in less than 0.1 ms) for very fast synchronization between two system boards during stop-dead-time.

Note that UltraSPARC III Cu modules cannot be mixed with the UltraSPARC III modules. The 10/01 version of the Solaris Operating Environment is required prior to installing the UltraSPARC III Cu module upgrades.

The following chart points out the high-level differences between the two CPU modules.

Feature	UltraSPARC III		UltraSPARC III Cu	
Speeds Available	750 MHz	900 MHz (optional)	900 MHz	1050 MHz
Can mix processor speeds?	Yes		No	
Solaris Operating Env Support	Solaris 8 (10/01 or newer)		Solaris 8 (2/02 or newer)	
OBP Revision	4.X or newer		4.5.X or newer	

Feature	UltraSPARC III		UltraSPARC III Cu	
Prefetch Setting	not available		optimized	
On-chip SRAM protection	some		additional ECC/parity	
SPECint2000 (peak)	396	466	533	610
SPECfp2000 (peak)	421	482	731	827

Table 3-1 Comparison of UltraSPARC III and UltraSPARC III Cu features

Instruction Pipeline

To meet clock rate and performance goals, the UltraSPARC III and UltraSPARC III Cu processors are designed with a deep, 14-stage pipeline, larger than any previous generation of SPARC processor. Each stage in the pipeline performs part of the work required to execute instructions. In Figure 3-2, instruction issue occupies stages A through J, integer execution stages R through D, with the data cache unit occupying stages E,C, M, and W and floating point occupying a parallel, “side” pipeline that is coincident with stages E through D of the integer pipeline. Other functional units in the UltraSPARC III and UltraSPARC III Cu processors have unique, internal pipelines.

A — Fetch address generation
P — Start of Instruction Cache access, Branch Predictor RAM access
F — Second cycle of Instruction Cache access
B — Calculate branch target addresses, decode first cycle of instructions
I — Instructions in Instruction Queue
J — Steer instructions to execution units
R — Integer Working Register File access, FP/Graphics instructions to FGU
E — Integer Execute stage, FP/Graphics Instructions access FP Register File, Data Cache access begins
C — Integer pipes write to Working Register File, FP/VIS execute stage, Data Cache delivers load data
M — Data Cache miss detection
W — Third cycle of FP/VIS instructions
X — Last stage for most FP and all VIS instructions
T — FP and Integer trap signaling
D — Integer and FP results to Register Files

Figure 3-2 The UltraSPARC III and UltraSPARC-II CU processors incorporate a 14-stage pipeline, larger than in any previous UltraSPARC processor.

One potential performance issue in the handling of pipelined systems occurs when an event like a data cache miss occurs. In events such as this, traditional designs issue a global pipe stall signal to freeze the pipeline. With the UltraSPARC III and UltraSPARC III Cu processors, the event is handled like a trap, with a non-stalling pipeline. The pipeline is allowed to drain, and the state restored by refetching instructions that were in the pipeline starting at the *A* stage. This approach avoids the wire delays common to large, high clock-rate processors.

Branch misprediction can also create a performance penalty in deep pipelines. In the UltraSPARC III and UltraSPARC III Cu processors, improved branch-prediction logic results in misprediction much less frequently. The UltraSPARC III and UltraSPARC III Cu processors also have a small amount of alternate path buffering in the *I* stage, so if a misprediction does occur, a few instructions are immediately available to start in the *I* stage, effectively halving the potential penalty.

UltraSPARC III Functional Units

In a single chip implementation, the UltraSPARC III and UltraSPARC III Cu processors feature very high levels of integration, which include the following six key components (Figure 3-3):

- Instruction issue unit (IIU) which feeds the processor pipelines
- Floating point unit (FPU) with three independent data paths (also processes graphics instructions)
- Integer execution unit (IEU) with four independent data paths
- Data cache unit (DCU) which manages all on-chip cache
- External memory unit (EMU) which control external cache as well as off-chip main memory
- System interface unit (SIU) to handle all external communications to other processors, memory systems, and I/O devices

Instruction Issue Unit (IIU)

The IIU feeds the execution pipeline with instructions, independently predicting control flow through a program and fetching the predicted path from the memory system. Fetched instructions are staged in a queue before dispatch to the integer or floating point units at up to four instructions/cycle. The IIU includes a 32 KB, four-way associative instruction cache, instruction address translation buffer, and a 16 K-entry branch predictor. A 20-entry instruction queue decouples the fetch and execution units, allowing each to proceed at its own rate.

Integer Execute Unit (IEU)

The IEU executes all integer data-type instructions, including loads, stores, arithmetics, logicals, shifts, and branches. Four independent data paths permit up to four instructions per cycle to be executed with the following per-cycle concurrent instruction mix: 1) two arithmetic, logical or shifts; 2) one load or store; 3) one branch.

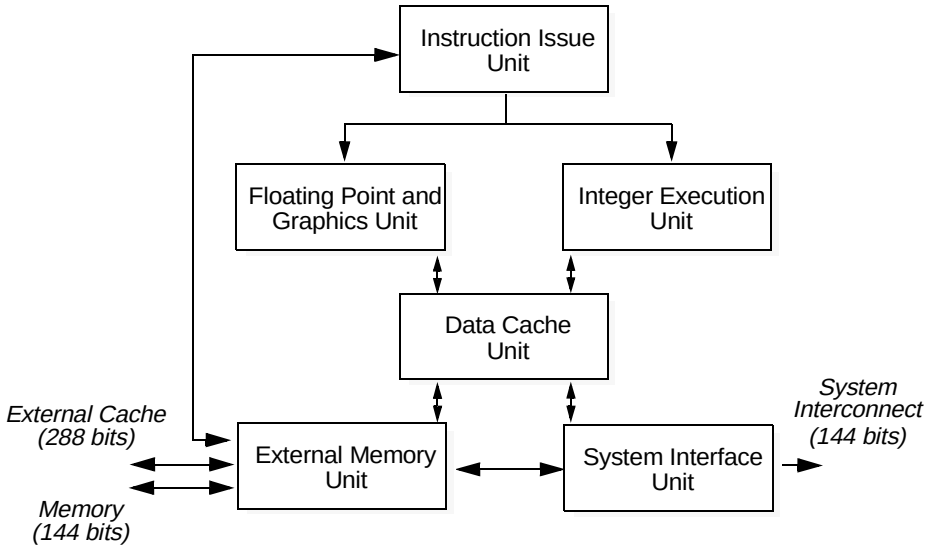

Figure 3-3 The UltraSPARC III and UltraSPARC III Cu processors functional block diagram

Data Cache Unit (DCU)

The performance impact of a processor's memory system becomes increasingly important as processor clock rates and performance increase. As a result, the design of the on-chip memory system in the UltraSPARC III and UltraSPARC III Cu processors were central to overall performance and scalability of the design. This was done by scaling both bandwidth and latency. Latencies were improved through the use of sum-addressed cache and improvements in both level-two cache and external memory latencies. On-chip memory bandwidths were scaled through the use of wave-pipelined SRAM designs for the on-chip caches and the use of a write cache for store traffic. As a result, UltraSPARC engineers were able to scale average memory latency from earlier UltraSPARC designs by more than the clock-rate multiplier.

The DCU manages all level-one on-chip cache memories and the data address translation buffer. The three first-level, on-chip caches include a 64 KB four-way associative data cache; a 2 KB, four-way associative prefetch cache; and a a 2 KB, four-way associative write cache.

Floating Point Unit (FPU)

The FPU incorporates all data paths and logic to execute floating- and partitioned fixed-point instructions. Three independent data paths can concurrently execute one instruction per cycle from each of the following classes: single, double, or partitioned divide and multiply; single, double, or partitioned add, subtract, or compare; and an independent division data path which lets a non-pipelined divide continue in parallel with the pipelined multiple and add data paths.

The FPU also incorporates most of the functionality associated with the VIS instruction set, with two independent execution units (one ALU plus one multiply) dedicated to graphics operations.

External Memory Unit (EMU)

The EMU controls both the level-two off chip data cache (up to 8 MB implemented with SRAM memory) and the main memory system (up to 8 GB implemented with SDRAM memory.)

Bandwidth to the level-two cache is kept high through the use of a 256-bit-wide data bus, delivering in a single cycle the entire 32 bytes of data needed to service a level-one cache miss. To support the 8 MB of level-two cache, the EMU is equipped with a 90-KB in-chip tag RAM, which also allows early detection of level-two cache misses, reducing the latency to main memory. Cache coherency in MP architectures is achieved by dedicating 50 percent of cycles of the on-chip, level-two cache tags to snoops from other processors.

Moving the main memory controller on-chip reduces memory latencies when compared with previous designs and scales memory bandwidth as processors are added. The memory controller supports up to 8 GB of SDRAM memory organized into four logical banks. In MP systems, the SDRAM banks can be interleaved across per-processor memory controllers. The 512-bit wide data bus to memory (4.8 GB/second transfer rate) minimizes the latency to complete data transfers, a critical design point since misses from large caches tend to cluster, with adjacent misses impacting performance in systems without high memory transfer rates.

System Interface Unit (SIU)

Charged with the task of all other off-processor communications (memory, other processors, and I/O devices) the SIU can handle up to 15 pending transactions with support for full out-of-order data delivery on each transaction, enabling memory banks in a MP system service a request as soon as a bank is available. All processor interfaces use error detection and/or correction codes to quickly detect errors. In the event of an error on the system bus, an independent 8-bit-wide “back door” bus allows the use of automated diagnostics to isolate the problem.

VIS Instruction Set

The UltraSPARC chip was the first microprocessor to fully support advanced multimedia and networking. By introducing a comprehensive set of multimedia instructions, known as the VIS instruction set, UltraSPARC provides enhanced hardware support for 2D and 3D graphics, video and audio processing, and image manipulation.

Pixel information in UltraSPARC III and UltraSPARC III Cu processors consists of four 8-bit integer values. These four values represent the color (RGB) and intensity information for a color image. For higher resolution images, like those used in medical or color imaging, UltraSPARC III and UltraSPARC III Cu processors also support 16-bit pixels. Support is provided both for band-interleaved images, with the various color components stored together, and band-sequential images that have all of the values for one color component stored together.

Intermediate results for advanced image manipulation are stored as 16- or 32-bit, fixed-data values. These provide an intermediate format with enough precision and dynamic range for filtering and image computations on pixel values. UltraSPARC III and UltraSPARC III Cu processors have several single-cycle instructions specifically tailored for manipulating these 16- and 32-bit components.

The UltraSPARC III and UltraSPARC III Cu processors also include a variety of instructions that are essential for advanced image manipulation. For example, it supports a filtering operation for scaling, rotating, and smoothing images. The filtering operation processes four pixels at a time, giving the UltraSPARC III and UltraSPARC III Cu processors an order of magnitude performance advantage over other processors.

Able to perform motion estimation in support of motion compensation — a technique used to code real-time video for compression — the UltraSPARC III and UltraSPARC III Cu processors can greatly accelerate multimedia applications. Motion estimation takes advantage of the minimal changes in the position of images from one frame to the next. The processor performs hundreds of comparisons for a region of the image, searching for a motion value that minimizes the estimation error. The error is calculated by summing the differences for each pixel in the region between a reference frame and a newer frame.

The UltraSPARC III and UltraSPARC III Cu processors are designed to minimize this compute-intensive operation by operating on eight pixels at a time. The motion compensation process for eight pixels requires eight subtractions, eight absolute values, eight additions, a load of eight pixels, an align of eight pixels, and one final addition. The UltraSPARC III and UltraSPARC III Cu processors perform this complex set of operations for eight pixels in just one clock compared to the minimum of 48 instructions and numerous clocks typically required by other processors. Because motion estimation is the dominant operation for compression, the UltraSPARC III and UltraSPARC III Cu processors' high throughput for this operation allows them to support compression for desk-top video conferencing without the aid of external circuitry.

Unique block load / store commands in the UltraSPARC III and UltraSPARC III Cu processors allow the processor to execute 64-byte loads and stores directly into main memory. The block load / store commands avoid "cache pollution" by eliminating data allocation to external cache. With the resulting high copy bandwidth, UltraSPARC III and UltraSPARC III Cu processors can move images directly from main memory to the screen fast enough to eliminate image flicker.

Although VIS was created to accelerate the manipulation of graphics data, it handles other types of partitioned data just as well. Other uses of VIS include the processing of audio data and encryption / decryption applications.

Fast Traps and Context Switching

Pioneered in the UltraSPARC-II processor, fast traps and context switching are supported in UltraSPARC III and UltraSPARC III Cu processors, with the trap entry mechanism architected to transfer control into the trap handlers very quickly. Eight registers, called "alternate globals," provide the trap handler

with a fresh register to use immediately upon entry. Moreover, the trap handler software need not store registers before it starts to execute, permitting very fast instruction emulation and extremely short interrupt response times.

The number of registers saved and restored between process executions is minimized, resulting in faster context switches. The architecture provides separate dirty bits for the original (lower) and the new (upper) floating-point registers. If a program has not modified any register in one of the sets, unnecessary register saves during a context switch can be avoided.

Memory Subsystem

The use of the Sun Fireplane interconnect (see below) allows considerable freedom in the design of the memory controller in Sun Blade 1000 and 2000 systems. Rather than a centralized memory controller (located in the system controller on previous desktop systems) the UltraSPARC III and UltraSPARC III Cu processors perform the memory controller function through its external memory unit (EMU). Logically the memory controller function is shared by all interconnect devices in the system.

This organization retains the shared physical memory model which has always been used by all SPARC systems and does not require any modification to the Solaris Operating Environment. All processors in the system are able to address all of memory, and all processors see a single, large, shared memory image.

External Cache Memory

Sun Blade 1000 and 2000 systems support CPU modules that feature 8 MB of external secondary cache (Ecache). Synchronous SRAMs are used for data and for tag. The datapath to the external cache is 288 bits wide and is ECC protected.

Main Memory

The memory system of the Sun Blade 1000 and 2000 workstations uses SDRAM DIMMs (dual in-line memory modules). There are eight DIMM sockets per system, divided into two physical banks of four DIMMs each.

Sun Blade 1000/2000 systems allow for the use of four DIMM module types of 128 MB, 256 MB, 512 MB, and 1 GB, yielding a system memory range from 512 MB to a maximum of 8 GB. To increase memory system performance, the Sun Blade 1000/2000 workstations employ a wide, dual 576-bit memory architecture. DIMMs must be added to the system in sets of four (quads). Each quad must use the same sized DIMMs, although different sized quads may be used.

Sun Fireplane Interconnect

The Sun Fireplane interconnect provides a number of key innovations, making it applicable to a range of present and future Sun systems.

Separate Address and Data Paths

One of the major architectural innovations of the Sun Fireplane interconnect is the ability to combine the simplicity of a single bus with the high bandwidth normally associated with a switch-based interconnect. This is accomplished with the complete separation and independence of address and data paths.

The address and data paths in most computer systems are very closely related, especially in their low-level sequencing, forcing a strong coupling between the transport of addresses and data between system components. The Sun Fireplane interconnect breaks away from this traditional methodology by completely separating the address and data paths — both at the topological level and in low-level sequencing.

Ordering on the Interconnect

One of the ways that the Sun Fireplane interconnect is able to achieve significant bandwidth gains is by allowing multiple transactions to be “in flight” on the interconnect at the same time. Allowing requests to the system interconnect to be fulfilled in a different order than they were issued reduces the time spent waiting for transactions to complete and permits the interleaving of transactions on the interconnect and within the processor.

Each of the devices on the Sun Fireplane interconnect maintains a record of the order in which it has issued requests, with each transaction tagged and identifiable by the requestor. Requests may be fulfilled in a different order than they were issued, similar to the way the UltraSPARC III and UltraSPARC III Cu processors allow instructions to be completed out-of-order.

In the Sun Blade 1000 and 2000 workstations, each device can have up to 15 outstanding 64-byte data transfers. This capability is important to maintain the performance of the UltraSPARC III and UltraSPARC III Cu processors as they use aggressive pre-fetching to fill both internal and external caches.

The Sun Fireplane Interconnect Sun Blade 1000/2000 Implementation

The address and command structure of the Sun Fireplane interconnect is based on the logical model of a bus. In the Sun Blade 1000 and 2000 workstations, the physical implementation mimics the local model with all address and command lines shared by all devices (Figure 3-4).

In the Sun Blade 1000 and 2000 workstations, the Sun Fireplane data path is a 288-bit on-chip bus implemented inside a set of six identical ASICs. This approach couples a wide data path with a high clock frequency of 150 MHz. The connection between the Sun Fireplane devices (UltraSPARC III processors and a custom I/O bridge) and the data path ASICs use a point-to-point model which allows the best possible clocking rate for chip to chip communication. The data path ASICs — called combined processor memory switch (CPMS) — also provide a switch between the internal data bus and the corresponding Sun Fireplane device.

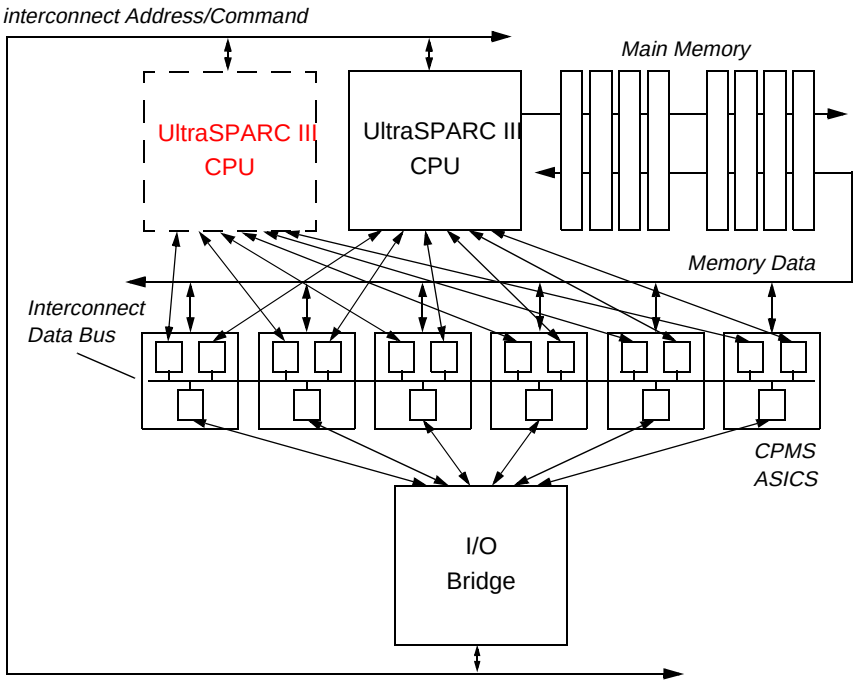

Figure 3-4 Sun Fireplane interconnect implementation in Sun Blade 1000 and 2000 systems

With the bus model of the Sun Fireplane interconnect, the need for a centralized “system controller” is eliminated, and control is distributed between all attached devices. The arbitration for the address and control lines is performed simultaneously by all devices which has the added benefit of reducing latency.

Cache Coherency

To maintain the high level of performance demanded by today’s applications, Sun Blade 1000/2000 systems use external level-two cache (8 MB) located on the processor module. Data that has been recently used, or whose impending use is anticipated, is retrieved and kept in cache memory — closer to the

processor that needs it. In a multi-processor, shared-memory system, the task of keeping all of the different caches within the system consistent requires assistance from the system interconnect.

The Sun Fireplane interconnect implements cache coherency through a technique known as “snooping.” With this approach, each cache monitors the addresses of all transactions on the system interconnect, watching for transactions that update addresses that it possesses. Since all processors need to see all of the addresses on the system interconnect, Sun Blade 1000 and 2000 systems connect the address and command lines to both processors, eliminating the need for a central controller.

Performance

The Sun Fireplane interconnect provides a number of key capabilities that help support the high-performance of the Sun Blade 1000/2000 workstations.

- *High bandwidth*

  The Sun Fireplane interconnect takes advantage of VLSI and packing technology improvements by widening the data path segments to 288 bits (256 bits of data, and 32 bits of ECC). With a 150-MHz clock rate, the Sun Fireplane interconnect delivers 2.4 GB per second of sustainable bandwidth per bus segment.

- *Low latency*

  Many multiprocessor systems provide a high-bandwidth interconnect at the expense of increased latency. Given the importance of the Sun Fireplane interconnect to future Sun multiprocessor systems, special care was taken to avoid increased latency.

  For example, integrating the memory controller with the CPU reduces latency by up to 20 percent in single-processor systems (10 percent in dual-processor systems) without software optimization. In addition, the Sun Fireplane interconnect implements special techniques for delivering data to the caches that minimizes latency. Finally, the UltraSPARC III and UltraSPARC III Cu processors provide a very sophisticated write-buffer with plenty of “head-room” so that even pathological behavior does not impact performance.

- *Innovative flow control*

  In most previous-generation systems, data is “pushed” onto the interconnect when a write transaction is issued by any device. This model requires a complex flow-control mechanism, which often suspended write traffic on the interconnect. In contrast, the Sun Fireplane interconnect introduces a novel method for data writes. With the interconnect, the target device “pulls” the data rather than having it “pushed” by the writer. A device which is a target of a write transaction simply informs the writer when it is ready to accept the data. This approach provides a balanced usage of system bandwidth between processors and translates into a more predictable response time under heavy load.

- *New signaling technology*

  The Sun Fireplane interconnect introduces a new low-level voltage signaling technology called dynamic transceiver logic (DTL). DTL drivers and receivers can easily be integrated on large ASICs while still using regular cooling and packaging technologies. In particular, DTL innovates by providing self-adjusting compensation circuitry that compensates automatically for voltage, temperature, and process variations in VLSI chips. Better control over timing margins translates into a higher clock frequency on wide data paths — such as the 144-bit bus between the UltraSPARC III and UltraSPARC III Cu processors and the CPMS ASICs that implement the Sun Fireplane bus.

- *Graphics performance*

  The Sun Blade 1000 and 2000 workstations allow the use of existing UPA-based Sun graphics options (see Graphics section). This is accomplished by providing a UPA64S interface — a simplified derivative of the original UPA — through the custom I/O bridge. UPA64S is a slave-only interface and all transfers to the graphics devices are performed by the UltraSPARC III and UltraSPARC III Cu processors.

  Sun’s scalable graphics devices benefit directly from the interconnect’s high bandwidth, providing better graphics performance for the end user. The Sun Fireplane interconnect provides an improvement over UPA by allowing the UltraSPARC III and UltraSPARC III Cu processors to issue one transaction per cycle whereas UPA required two cycles. In addition, the high number of outstanding transactions allowed on the Sun Fireplane interconnect delivers higher throughput to graphics devices.

Fibre Channel

Several factors are contributing to rapid changes in storage systems. One is the increasing value of information. Shortened market windows and development cycles have made information both a competitive weapon and an asset, its proper exploitation critical to success. Today, information security and the ease with which it can be accessed has a direct effect on its value to the enterprise, resulting in more data being kept on-line and more stringent processes being established to ensure that it remains available when needed. Another factor affecting storage systems is the changing nature of the information itself. No longer simple character data, information comes in many forms and has a longer life. Images, drawings, photographs, faxes, audio, and video data are now kept on-line for years.

The most popular of today's high-end storage protocols, SCSI, is reaching its performance limits. SCSI's other liabilities include requiring prohibitively short distances between devices, expensive and complex cabling, and impedance matching problems that restrict its use. Running at a maximum of 40 MB/second, half duplex, UltraSCSI performance is a poor match for today's distributed environments. Higher I/O rates, larger datasets, and distributed computing architectures are driving more data through systems and networks, and as this trend continues, SCSI is becoming an increasingly severe bottleneck for systems, applications, and users. Increasingly, Fibre Channel is emerging as a replacement for SCSI.

Fibre Channel Arbitrated Loop (FC-AL)

Fibre Channel is an industry-standard, high-speed serial data transfer interface that can be used to connect systems and storage in point-to-point or switched topologies. Fibre Channel arbitrated loop (FC-AL), developed with storage connectivity in mind, is an enhancement to the standard that supports copper media and loops containing up to 126 devices, or nodes. FC-AL loops support hot-plug devices and tolerant of failures.

The FC-AL standard supports bandwidths of 133 Mb/second, 266 Mb/second, 532 Mb/second, 1.0625 Gb/second, and 4 Gb/second (proposed) at distances of up to ten kilometers. The FC-AL implementation in the Sun Blade 1000 and 2000 workstations supports the 1 Gb/second standard, or about 100 MB/second after accounting for overhead.

In addition to its strong performance characteristics, Fibre Channel also provides powerful networking capabilities, allowing switches and hubs to allow the interconnection of systems and storage into tightly knit clusters. Such clusters can provide high levels of performance for file service, database management, or general purpose computing. Because it is able to span up to 10 kilometers between nodes, Fibre Channel allows the very high-speed movement of data between systems — even those that are geographically separated from one another.

Feature	Benefits
• 200 MB/sec. data rates (full duplex)	• Throughput to match modern computing, peripheral and networking performance
• 127 devices per loop	• Simpler, less expensive equipment requirements
• Networking capability	• Easier, simpler configuration of high performance compute, file, and storage servers and clusters
• Up to 10 km between nodes using optical fiber, up to 30 meter using cable	• More flexible and secure hardware configurations
• Hot pluggability, dual porting	• Support for high availability and disaster-tolerant configurations, disk arrays
• Use of cyclic redundancy checks to provide data integrity	• Better security and reliability
• Simple serial protocol over a copper or fibre medium	• Less expensive, less complex cable requirements
• Use of standard protocols like IP and SCSI	• Reduced impact on system software and firmware, leverages existing code

Table 3-2 Technical advantages of FC-AL

FC-AL is also a high-reliability interconnect. The interface is robust enough to allow multiple devices to be removed from the loop at one time with no interruption in data transfer. In addition, the interface attaches sophisticated error-detecting codes to each packet of user data. These codes are check by the receiver of the data, which request a re-send if there is any discrepancy.

FC-AL-based storage systems enable the creation of new solutions that take full advantage of some impressive technical specifications (Table 3-2).

The technical advantages of FC-AL alone would be enough to convince most that it represents the future of high-speed peripheral interconnects, but FC-AL enjoys other important characteristics:

- *Industry standard*

  The FC-AL development effort is part of the ANSI/ISO accredited SCSI-3 standard, helping to avoid the creation of non-conformant, incompatible implementations.

- *Broadly supported*

  Major system vendors (Sun, HP, DEC, Compaq, and others) are implementing FC-AL interfaces, as are major disk drive and storage subsystem vendors. Such wide support encourages competition, lower costs, and user choice.

- *Greater flexibility*

  Fibre Channel can also be used to do more than disk I/O. The Fibre Channel specification supports high-speed system and network interconnects using a wide variety of popular protocols, including HIPPI, TCP/IP, IPPI, FDDI, ATM, as well as SCSI. Nearly all of the interconnect requirements of even the largest enterprises can be met by Fibre Channel, promising lower costs, easier administration, and the easy deployment and redeployment of computing resources.

PCI Connectivity

PCI provides a high-performance bus that is optimized for high-speed data transfers. System-board resident, the PCI bus is used as an interconnect between highly integrated components and subsystems, such as peripherals, add-on boards, and memory systems. The processor, main memory, and the PCI bus are connected through a PCI host bridge and interconnected by the Sun Fireplane interconnect on the Sun Blade 1000 and 2000 workstations.

The PCI bus is based on the industry standard PCI specification version 2.1. Unlike most standards, the PCI specification is very broad. It covers everything from multiple form factors and voltages to connector types.

Sun has chosen to implement the most common PCI options available:

- 33-MHz (standard) and 66-MHz buses
- 32-bit or 64-bit cards

- 5-volt cards (33 MHz bus) and 3.3-volt cards (33- and 66-MHz bus)
- 7-inch (short) cards
- 12-inch (long) cards
- PCI Specification 2.1 compliance
- Low power operation, Energy Star compliance

To provide sustained high-performance, Sun Blade 1000 and 2000 systems support four slots distributed among two independent, 64-bit PCI buses. One PCI bus is capable of running at up to 66 MHz and supports a single 3.3 volt card slot as well as the Fibre Channel arbitrated loop (FC-AL) controller. 33-MHz cards that are capable of 3.3 V operation may also be used in the 66-MHz slot but may impact disk performance.

The second PCI bus supports up to three 3.3 or 5 V, 33-MHz PCI cards, and supports several on-board devices such the UltraSCSI controller, and a bridge chip which controls Ebus (low-speed serial devices), Ethernet, IEEE 1394, and USB among others. Despite the fact that all four slots are 64-bit capable, 32-bit cards can be used as well without forcing the entire bus to operate in 32-bit mode. Each slot can supply up to 15 W of power. See Table 3-3 for a summary of slot configuration data.

	PCI Slot Number			
	1	2	3	4
33/66-MHz Clock	✓			
33-MHz Clock		✓	✓	✓
5-Volt or Universal Cards		✓	✓	✓
3.3-Volt or Universal Cards	✓			
32-bit Slot	✓	✓	✓	✓
64-bit Slot	✓	✓	✓	✓

Table 3-3 Available configurations, speeds, and voltages for Sun Blade 1000 and 2000 workstation PCI slots

Sun supports a variety of PCI-based adapter cards, including networking cards along with video, SCSI, and high speed serial and parallel interfaces. In addition, Sun has developed a host of third-party alliances to develop PCI hardware and software that is certified for operation on Sun Blade 1000 and 2000 systems running the Solaris Operating Environment.

Peripherals, Networking, and Back Panel

In addition to PCI connectivity, Sun Blade 1000 and 2000 models support a full complement of I/O devices through connectors on the back panel (Figure 3-4):

- 10/100BASE-T Ethernet network connector
- Audio ports
- Serial-ports and Centronics-compatible parallel port
- UltraSCSI
- USB Type A (four ports, one for keyboard, one for mouse)
- IEEE 1394 (two ports)
- FC-AL (one port)

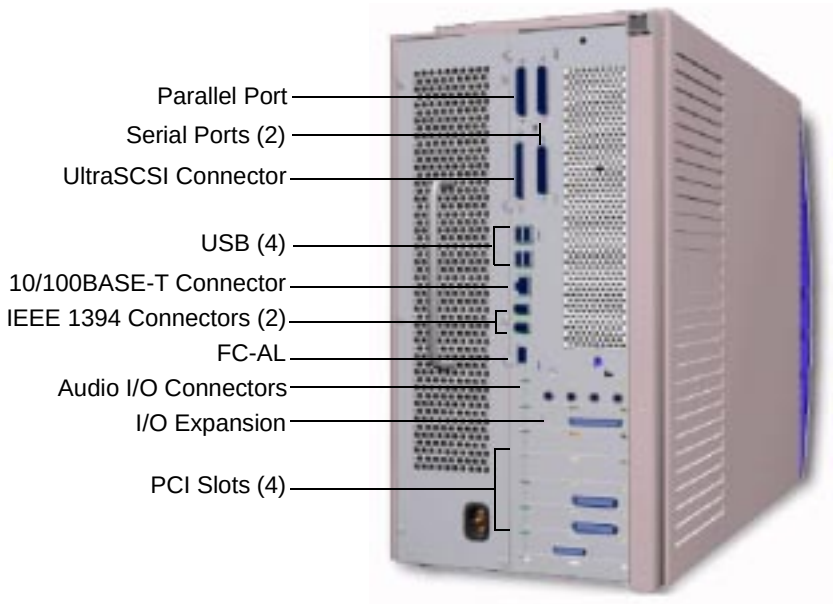

Figure 3-5 Sun Blade 1000 and 2000 workstations feature broad connectivity and expansion options

Monitors

Sun Blade 1000/2000 systems support a family of Sun monitors including:

- 17-, 21-, and 24-inch color monitors
- 18- and 24-inch color flat-panel (LCD) displays

Note that the 24-inch displays are not supported by Sun Elite3D m6 graphics.

Ethernet

To support higher performance network connectivity, all Sun Blade 1000 and 2000 workstations support 100 Mb/second Fast Ethernet. Fast Ethernet technology from Sun is backwards compatible with 10-Mbps Ethernet, with the speed being autosensed by the interface.

Fast Ethernet (100BASE-T) is a direct extension of the 10BASE-T Ethernet standard, but is capable of supporting a wider range of application requirements with its greater throughput. Particularly compelling is its compatibility with the installed base of wiring currently employed for 10BASE-T, making it the most cost-effective migration path for most users. Like its predecessor, the standards for Fast Ethernet are well defined and accepted throughout the industry, and a large number of compatible products are available from a variety of vendors.

The Ethernet interface on Sun Blade 1000/2000 systems support access to a Category 5, twisted-pair cable through an RJ-45 connector.

Audio

A plug-in logic board provides Sun Blade 1000 and 2000 systems with high-quality audio circuitry. An internally mounted speaker is provided for systems without attached external speakers. The audio subsystem of the Sun Blade 1000 and 2000 workstations supports a variety of standard sampling rates, including the following:

- 16-bit, 48-KHz digital audio tape (DAT)
- 16-bit, 44.1-KHz CD
- 16-bit, 16-KHz medium-quality audio for applications such as speech processing
- 8-bit, 8-KHz standard telephony

The backpanel provides a variety of audio connectors allowing the Sun Blade 1000 and 2000 workstations to be connected to standard audio equipment such as amplifiers and tape recorders. A small mono external microphone is provided, making audio input and output more convenient.

Parallel Port

The parallel port can be operated using programmed I/O or DMA. Its interface direction, timing, and protocol is programmable to meet the wide variety of Centronics interfaces that exist on peripheral devices. Access to the parallel port is through a DB25 connector located on the backpanel.

Serial Ports

RS-232C and RS-423 serial ports provide a convenient way to connect a Sun Blade 1000 or 2000 system to devices such as modems and terminals. All systems include two serial ports for use with DB25 connectors (synchronous and asynchronous) with standard pinouts on each. Synchronous transfers can occur at 64 Kbps, while asynchronous transfers can occur at up to 460 Kbaud, significantly faster than earlier Sun workstation systems.

SCSI

Sun Blade 1000 and 2000 systems support the 40 MB/second UltraSCSI (Fast-20) interface. The number of Fast-20 SCSI peripherals that can be connected to the same daisy chain is dependent on cable length, with external peripherals accessible through a 68-pin “D” type SCSI connector. While the UltraSCSI port is compatible with slower SCSI devices, their use on the UltraSCSI bus helps reduce overall performance.

USB

Sun Blade 1000 and 2000 systems provide four USB ports on the back panel for support of both low-speed (1.5-Mbps) and full-speed (12-Mbps) devices. USB devices support hot-plug capabilities so device attachment is automatically detected and drivers and software automatically configured. Devices such as Iomega ZIP drives and various PostScript™ printers are supported via standard administration utilities. The Solaris Operating Environment supports a maximum of 126 USB devices and the bus can be easily extended via self- or bus-powered hubs.

A Sun Type-6 USB keyboard and USB opto-mechanical mouse are standard with each Sun Blade 1000 and 2000 systems. Users can choose between the common IBM AT 101-key keyboard or one with a UNIX layout. Both keyboards include keys for controlling audio and for turning the system on and off.

Sun Blade 1000 and 2000 Workstations Graphics

4

Sun understands that graphics is rapidly shifting away from being a specialized requirement of technical users and is becoming an essential part of nearly every computing discipline. Sun believes that as this trend continues, the standards for graphics functionality and performance will continue to rise. Sun Blade 1000/2000 systems anticipate this trend by providing standard graphics capabilities that rival the performance of products available only as options on other desktop systems.

Rather than viewing graphics as an add-on subsystem, Sun engineers have taken a systematic approach that includes graphics as a highly integrated core element of system architecture. From the beginning Ultra systems were designed with a graphics architecture that could not only withstand the rigors of current requirements, but one that could excel and scale for years to come. Today this approach has resulted in several key areas of focus:

- *Performance and functionality*

  Sun strives to build superior performance and extensive functionality into its graphics products with more standard functionality in each new generation. Features like 24-bit graphics, video decompression, 3D graphics, and high resolution are a standard part of the system, not expensive options.

- *Cost-effective platforms*

  At the same time, Sun works to design new graphics systems that are affordable, even in large deployments. At the low end this means designing systems with advanced graphics features that are economical enough to be included as standard equipment on high-performance desktop systems. On

higher-end systems this approach implies innovation and a high level of integration and use of new technologies. With each new generation, Sun continues to drive high-end functionality into continually lower-priced platforms.

- *Software compatibility*

  Sun recognizes that the real costs associated with any platform are likely to be software related — the days of releasing accelerators with proprietary graphics languages are long gone. Any new graphics system Sun designs must be compatible with the large set of graphics libraries already written, and must transparently accelerate software written to existing APIs.

The Sun Blade 1000/2000 systems were designed to support a large range of graphics accelerators and is designed to support multiple displays. The chart below gives a comparison summary of the supported graphics accelerators.

	Sun PGX64	Sun Creator3D	Sun Elite3D	Sun Expert3D-Lite	Sun Expert3D	Sun XVR-1000
Max # supported	4	2	2	3	2	2
Bus	PCI 32-bit, 33 MHz 64-bit, 66 MHz	UPA	UPA	PCI 64-bit, 66 MHz	PCI 64-bit, 66 MHz	UPA
Max. 2D resolution	1920 x 1200	1920 x 1200	1280 x 1024	1920 x 1080	1920 x 1200	1920 x 1200
Max. 3D res.	—	1280 x 1024	1280 x 1024	1920 x 1080	1920 x 1200	1920 x 1200
Stereo resolution	not supported	960 x 680 @ 112 Hz	960 x 680 @ 112 Hz	1280 x 800 @ 112 Hz 1152 x 900 @ 120 Hz	1280 x 1024 @ 112 Hz	960 x 680 @ 108, 112Hz 1152 x 900 @ 120 Hz 1280 x 800 @ 112 Hz 1280 x 1024 @ 96-112 Hz
Memory Type	SGRAM	3DRAM	3DRAM	SDRAM	SDRAM	SDRAM, 3DRAM
Frame buffer memory	8 MB	15 MB	15 MB	32 MB	64 MB	72 MB
On-board texture memory	—	system memory	16 x 16 texel cache	16 MB	64 MB	256 MB
Geometry perf. (tri./sec.)	—	1.5 M	5.9 M	4.1 M	6.0 M	19.1 M
Texture fill rate (pixels/sec.)	—	Host bound	56 M	88 M	118 M	163 M

Table 4-1 Graphics accelerator feature comparison

	Sun PGX64	Sun Creator3D	Sun Elite3D	Sun Expert3D-Lite	Sun Expert3D	Sun XVR-1000
APIs supported	OpenGL, XGL™, XIL, Xlib, Java 3D™			OpenGL, Xlib, Java 3D (XIL via shared memory only)		

Table 4-1 Graphics accelerator feature comparison

The graphics accelerators can be mixed within a single system. The specific mix and match rules for these graphics options are described below. In essence, you can mix and match cards as you want, until you run out of slots. (The grayed-out areas in the table indicate slots that are incompatible with the specified graphics card.

	Total # Supported	UPA Slot 0	PCI Slot 4, 33 MHz	UPA Slot 1	PCI Slot 3, 33 MHz	PCI Slot 2, 33 MHz	PCI Slot 1, 66 MHz
Sun Creator3D	2	X		X			
Sun Elite3D m6	2	X		X			
Sun PGX 64	4		X		X	X	X
Sun Expert3D-Lite	3		X		X	X	
Sun Expert3D	2		X		X	X	
Sun XVR-1000	2	X		X			

Table 4-2 Graphics slot configuration options

Configuration Rules

- A maximum of four cards can be installed in any system.
- Sun Elite3D graphics cards take up a UPA slot and the adjacent PCI slot. For example, if you install a Sun Elite3D m6 card in UPA Slot 0, you cannot install anything in PCI Slot 4. The same is true for UPA Slot 1 and PCI Slot 3.
- Installing the Sun PGX64 card in the 66-MHz PCI slot slows performance of the entire 66-MHz PCI bus to 33 MHz.
- The Sun Expert3D and Expert3D-Lite cards cannot not be installed in the 66-MHz PCI slot.

The sections below describe the different graphics options in more detail.

Sun PGX64 Graphics

Sun PGX64 frame buffers are available as an option in Sun Blade 1000 and 2000 systems. Sun PGX64 graphics provides a low-cost, 8-bit or 24-bit color graphics that is accessible via a standard VGA connector (HD15) or 13W3 video adapter.

Sun PGX64 graphics uses the ATi Rage XL chipset, which is tied directly to two 4-MB SGRAM chips (8 MB total). The bus interface ASIC provides the host bus (33 MHz or 66 MHz) PCI interface for the graphics board and is the graphics engine.

A low-cost, high-volume graphics board, the Sun PGX64 frame buffer provides a host of standard features for Sun Blade 1000 and 2000 workstation users:

- Low-cost, PCI-based 8-bit and 24-bit color
- 33-MHz, 32-bit, 5-volt PCI card in short form factor (less than 7-inch length)
- 8 MB of SGRAM
- Simultaneous support for 8-bit applications on a 24-bit windowing environment
- 24-bit support for resolutions up to 1920 x 1080 @ 76 Hz
- 8-bit support for 1920 x 1200 @ 70 Hz
- Low power consumption (~4 Watts)

Sun Creator3D Graphics

To design Sun Creator3D graphics, Sun engineers built on lessons learned with other architectures, enabling them to locate acceleration technologies in the system where they would most benefit graphics performance. This approach resulted in a highly integrated, modular architecture that tightly couples the CPU, the system interconnect, the frame buffer and graphics accelerator.

Sun Creator3D graphics provides a wealth of features which make it ideal for a range of applications including imaging, video, multimedia, as well as 2D and 3D graphics applications. Sun Creator3D graphics systems provide fast 8- and 24-bit window system and imaging performance, but add key graphics features like double-buffering and Z-buffer support for accelerating 3D solids and animation applications. Sun Creator3D graphics dramatically accelerates high-end 3D functionality like double buffering, triangle and quad rendering, and lighting and shading.

Sun Creator3D graphics provides 96 bit planes, including full 24-bit double-buffer planes required for smooth animation. A 28-bit Z-buffer enables hardware assisted hidden surface removal for dynamic rendering of 3D objects. Sun Creator3D graphics features include:

- High-performance, low-cost, 24-bit true color standard
- Transparent acceleration for X11 and XIL graphics libraries
- Partial acceleration for the OpenGL 3D API
- Simultaneous 8-bit and 24-bit visual support
- Multiple hardware colormaps
- Adjustable gamma correction
- 4-bit pseudocolor overlay support (non-destructive)
- High resolution (1280 x 1024 @ 76 Hz non-interlaced)
- Stereo-ready (960 x 680 @ 112 Hz non-interlaced)
- DDC2B monitor serial communication with EDID support
- 8-bit SOV-compliant pseudocolor overlay
- Transparent acceleration for 3D APIs (OpenGL and Java 3D)
- 3D solids, dynamic shading, rotation, and Z-buffered acceleration
- Full double-buffered 24-bit true color, 8-bit overlay, 28-bit Z-buffer, 4-bit stencil
- 24-bit single-buffered high resolution support (1920 x 1200) with Sun 24-inch monitor

Sun Creator3D Graphics Theory of Operation

With Sun Creator3D graphics processing is balanced across the entire system to take advantage of all available resources. The table below lists the parts of the system that are responsible for accelerating different graphics operations.

Functionality	Responsible System Component
Window System and 2D Graphics	Sun Creator3D Graphics Module
Imaging and Video	UltraSPARC (VIS Instruction Set), Sun Creator3D Graphics Module
3D Graphics Pipeline	UltraSPARC (Floating Point Unit), Sun Creator3D Graphics Module

Table 4-3 Sun Creator3D graphics functionality

The Sun Creator3D graphics module (Figure 4-1) contains three key components — a frame buffer controller ASIC, 3D-RAM, and a RAMDAC.

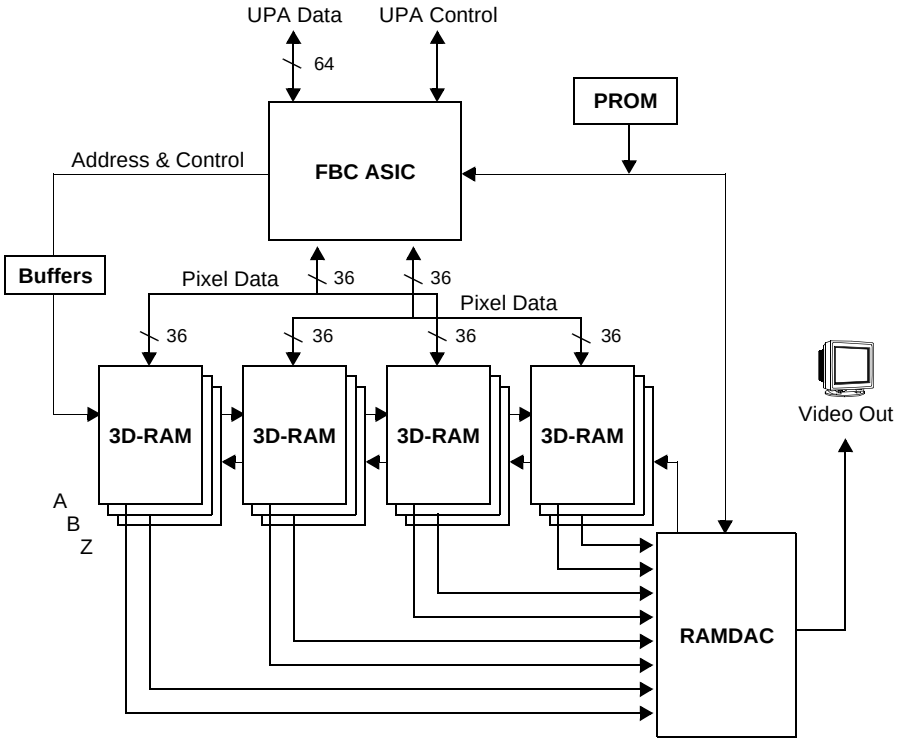

Figure 4-1 The Sun Creator3D graphics accelerator

- *Frame Buffer Controller ASIC*

  The frame buffer controller ASIC (FBC2) provides an interface to the UPA64S memory interconnect in Sun Blade 1000 and 2000 systems and provides acceleration of graphics rendering. Key graphics primitives such as Bresenham lines, polygons fills, and text scrolling are implemented in ASIC technology to provide substantially higher window system performance.

- *3D-RAM*

3D-RAM provides a solution to one of the traditional bottlenecks in 3D graphics hardware — namely the rate at which pixels can be drawn into a frame buffer for Z-buffered rendering. Historically, the performance of hidden surface removal algorithms has been limited by the pixel fill rate of 2D projections of 3D primitives.

Working together, Sun Microsystems and Mitsubishi Electronics created breakthrough technology for implementing fast, inexpensive 3D frame buffers. 3D-RAM integrates DRAM and an SRAM cache on a single chip along with an on-chip arithmetic logic unit. The result is a 10-Mbit part that handles 3D graphics ten times faster than conventional VRAM, at a lower system cost.

- *RAMDAC*

  Finally, a highly flexible, dual-mode RAMDAC provides high-performance 8-bit and 24-bit color space management. The RAMDACs employed by Sun Creator3D graphics systems integrate functionality that was previously spread throughout the system in other designs. This approach provides a higher level of integration and produces a considerable cost savings.

Sun Elite3D m6 Graphics

Sun Elite3D m6 graphics-equipped systems accelerate applications that manipulate large numbers of complex 3D solids for use in MCAD, geotechnical, animation, or related fields. Sun Elite3D m6 graphics dramatically improves performance in double-buffering, triangle and quad rendering, and lighting and shading without sacrificing fast 8- and 24-bit window system, imaging, or video performance.

Sun Elite3D m6 graphics-equipped systems provide 88-bit planes, including full 24-bit double-buffer planes as required for smooth animation. A 28-bit Z-buffer is included to provide hardware assistance for hidden surface removal and dynamic rendering of 3D objects.

Sun Elite3D graphics features include:

- Simultaneous 8-bit and 24-bit visual support
- Multiple hardware colormaps
- Adjustable gamma correction
- 8-bit SOV-compliant pseudocolor overlay
- Transparent acceleration for X11 and XIL graphics libraries

- Transparent acceleration for 3D APIs (OpenGL, and Java3D APIs)
- 3D solids, dynamic shading, rotation, and Z-buffered acceleration
- Full double-buffered 24-bit true color, 8-bit overlay, 28-bit Z-buffer (floating point), 4-bit stencil (with full support for OpenGL stencil functions)
- High resolution (1280 x 1024 @ 76 Hz non-interlaced)
- Stereo-ready (single pass, 960 x 680 @ 112 Hz non-interlaced)
- DDC2B monitor serial communication with EDID support

The Sun Elite3D m6 graphics — featuring six powerful floating-point processors — also provides support for a range of important 2D and 3D functions (Table 4-4).

2D Operations	3D Operations	Other Features
• Bresenham lines	• Accelerated dots, lines, triangles, and quads	• Viewport clipping
• Polygons	• Hardware antialiasing of dots and lines	• Window ID clipping
• Font support	• Hardware support of large antialiased dots up to 10 pixels in diameter	• Hardware line patterning for all lines
• Rectangle fill	• Gouraud shaded triangles	• 32 x 32 area pattern
• Fast block clear	• Specular lighting	• Flexible blending operations
	• Hardware per-pixel depth-cue	• Full set of Boolean operations
	• Hardware transparency (both alpha-blended and screen-door)	• Stateless frame buffer available in both 8 and 24 bits
	• Alpha interpolation per pixel	• Full plane mask
	• Texture map support	
	• Compressed 3D geometry decompression	

Table 4-4 Functionality supported by the Sun Elite3D m6 graphics accelerator

Sun Elite3D Graphics Theory of Operation

The Sun Elite3D graphics module is comprised of a number of specialized ASICs for interface and control (*AFB-Command*), floating point operations (*AFB-Float*), and pixel drawing (*AFB-Draw*). The Sun Elite3D graphics module uses twelve 3D-RAM chips to provide a 1280 x 1024 double-buffered 24-bit frame buffer with a 28-bit depth buffer, as well as a Bt498+ RAMDAC

(Figure 4-2). To avoid difficulties implementing switched bidirectional buses at 120 MHz, the Sun Elite3D graphics design uses unidirectional, point-to-point buses for all three of its internal high-speed buses. One of the busses (*FD-Bus*) runs at 800 MB/second.

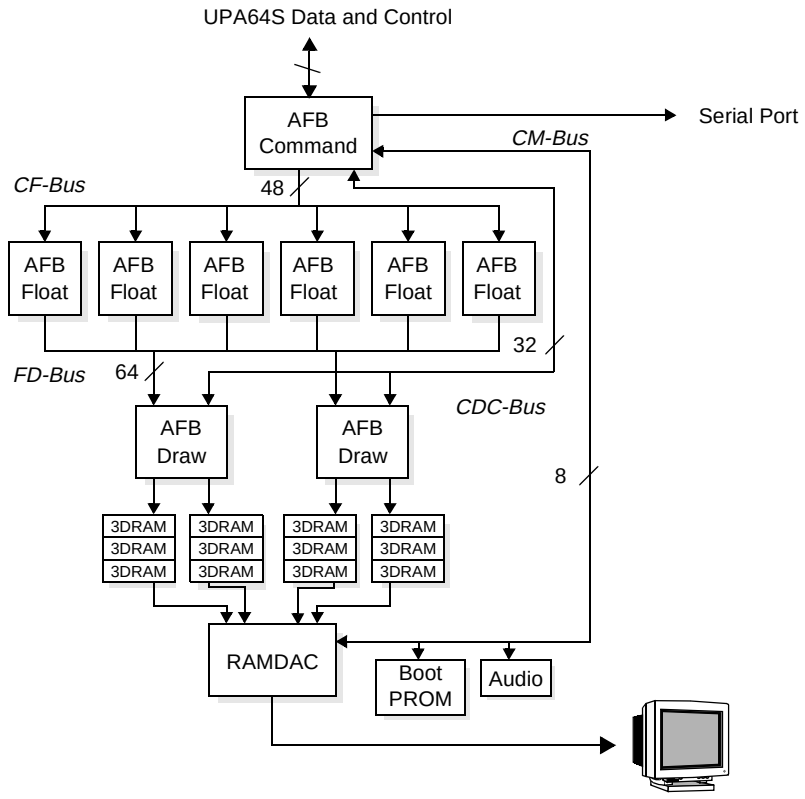

Figure 4-2 The Sun Elite3D m6 graphics accelerator

The *AFB-Command* ASIC buffers and converts incoming 3D geometric data to independent primitives (triangles, lines, dots) which are then distributed to the six floating-point chips for further processing. In addition to the regular data input functions, AFB-Command has a decompression unit capable of converting highly compressed 3D geometric data back into the standard formats required by the rest of the graphics pipeline. Software like Java 3D APIs provide for geometry compression. The AFB-Command chip also permits the efficient reading and writing of pixels to and from the frame buffer memory.

The *AFB-Float* components are designed to transform, light, clip, and set up primitives which are passed to it from the AFB-Command chip. Six floating point units are used on the Sun Elite3D m6 graphics. This module enhances performance by providing algorithm-specific circuits dedicated to just one (or a few) stage(s) of the graphics pipeline.

AFB-Draw takes in screen-space (fully transformed and lit) primitives and renders them into the frame buffer, drawing dots, lines and triangles as efficiently as possible. It also performs optional antialiasing on dots and lines. AFB-Draw contains edge walking and span interpolation circuitry to render individual pixels.

Other functionality includes:

- Single-pixel dots, antialiased dots, and large antialiased dots
- X11 Bresenham lines
- X11 Bresenham edge 2D polygons
- DDA lines and antialiased DDA lines
- DDA Gouraud interpolated triangles
- DDA triangles with texture mapping
- Screen aligned rectangular patterned fills and vertical scrolls
- Fonts (stencil)

Support is also included on a per pixel basis for:

- Alpha channel blend / transparency
- Screen door transparency
- Depth cueing
- Write-masks
- WIDs (Window IDs)

Key to Sun Elite3D graphics' performance is the rate at which AFB-Draw can render 24-bit depth-cued pixels into the 3D-RAM based frame buffer — nearly 400 million pixels per second. To achieve these high rates, the 3D-RAM is four-way interleaved, with two AFB-Draw ASICs to control two interleaves each.

AFB-Draw also handles all pixel operations such as blending, depth-cueing, Boolean operations, bit masks, fonts, window-ID clipping, viewport clipping, and so forth. There is logic in the chip to allow "direct port" accesses to slip in between "accelerator port" access as needed. AFB-Draw also supports frame buffer read operations over the UPA64S interface.

Sun Expert3D Graphics

Increasingly, user productivity is tied to better system interactivity — particularly when operating on complex graphical data. The need for high-end graphics support continues to increase along with the desire to leverage the skills of valuable technical personnel. These key users need to simulate and visualize complex problems and data in order to gain insight and understanding — tasks frequently essential to the organization's core mission or business. Examples of these demanding applications include high-end MCAD / MCAE, seismic data visualization for oil and gas exploration, terrain mapping for GIS, auto-styling applications in mechanical computer-aided design, digital content creation, and medical imaging applications that rely on 3D graphics to analyze patient data.

Sun Expert3D graphics offers high-end 3D graphics performance and functionality including support for accelerated texture mapping with on-board texture memory and state-of-the-art handling of color and gamma correction. The Sun Expert3D accelerator supports monitor refresh rates up to 112 Hz and provides double-buffered / Z-buffered support for 3D graphics up to resolutions of 1920 x 1200 with support for steroscopic 3D applications up to 1280 x 1024 resolution.

Sun Expert3D graphics provides significant features not found in other accelerators:

- *On-board 3D geometry accelerator*

  Accelerates 3D geometry up to 6 million triangles per second with up to 3.2 GFLOPS of floating point performance

- *On-board rasterization engine*

  Performs triangle setup, texture processing, and all pixel operations in rasterization, with a peak performance of 143 million pixels per second (trilinear) fill rate

- *64 MB of on-board frame buffer memory*

  Supports 24-bit 2D and 3D graphics up to 1920 x 1200 and all Sun displays, including the Sun 24-inch monitor. Allows users to display all windows with minimal or no overlapping. 103 dpi at 1920 x 1200 provides more image detail and higher accuracy

- *64 MB of on-board dedicated texture memory*

  Provides significant texture-mapping acceleration, allowing complex true-color 2D and 3D textures for applications that require texture mapping

- *Supports stereoscopic video graphics at 1280 x 1024 resolution*

  Allows display of 3D data in stereoscopic graphics mode at a high resolution providing enhanced realism for immersive applications and environments.

- *Multi-display support*

  Allows users to run multiple displays when multiple Sun Expert3D graphics cards are installed. Enables applications to span multiple displays for command and control applications, animation, automotive design and analysis, and other demanding applications.

- *True-color double- and Z-buffering at up to 1920 x 1200 resolution*

  Allows users to employ large-screen super-high-resolution monitors, including Sun's 24-inch HDTV-style monitor to display 2D and 3D graphical data.

- *32-bit Z-buffer at all resolutions*

  Provides a high of three-dimensional accuracy, eliminating anomalies such as the flickering of objects when moving around in a 3D image

Implemented as a full-length PCI graphics card, Sun Expert3D graphics features internal I/O ports for multi-viewing and external I/O ports for external video synchronization and stereo capabilities. Connecting these multi-viewing ports together, allows frame locking and rate locking of multiple Sun Expert3D graphics cards in a single workstation in order to display synchronous multi-screen applications.

Sun Expert3D graphics provides automatic acceleration for Sun 2D and 3D graphics APIs including Xlib, OpenGL, and Java 3D APIs. For example, Sun Expert3D graphics provides acceleration for the following Sun OpenGL for Solaris Operating Environment API operations:

- Points (2D, 3D, wide)
- Vectors (2D and 3D lines and linestrips; wide and stippled)
- Polygons (triangles, triangle strips, quads, quad strips, polygons, and point/line polygon mode)

- Antialiased points, vectors, and polygons
- Image support (multiple formats, zoom, bilinear scaling, color matrix, and color tables)
- Alpha operations
- Scissoring
- Window clipping
- Masking
- Double-buffered overlay
- Fogging (linear, exponential, exponential**2, user-defined)
- Texture mapping (point, bilinear, trilinear, and multiple internal formats)
- Stencil operations
- Dithering
- Rich set of blending operations
- Depth buffering (32 bit, integer and floating point depth formats)
- Hardware Pbuffer operations
- Fast window clears
- Fast window-mode double buffering
- Frame-sequential stereo support
- Texture mapping features:
- Support for 64 MB of texture memory
- 2D and 3D nearest / linear / mip-mapped textures
- 1, 2, 4, or 8 bytes / texel
- 1, 2, 3, or 4 components / texel
- Texture scale and bias; texture lookup table
- Texture environment blending functions
- Stencil plane support

Sun Expert3D Architecture

The Sun Expert3D graphics system is comprised of several core components (Figure 4-3):

- The *bus interface ASIC* provides the host bus (64-bit PCI) interface for the card. The ASIC provides an interface for supporting up to 64 MB of local request memory — referred to as direct burst memory. The Sun Expert3D graphics features 8 MB of direct burst memory.

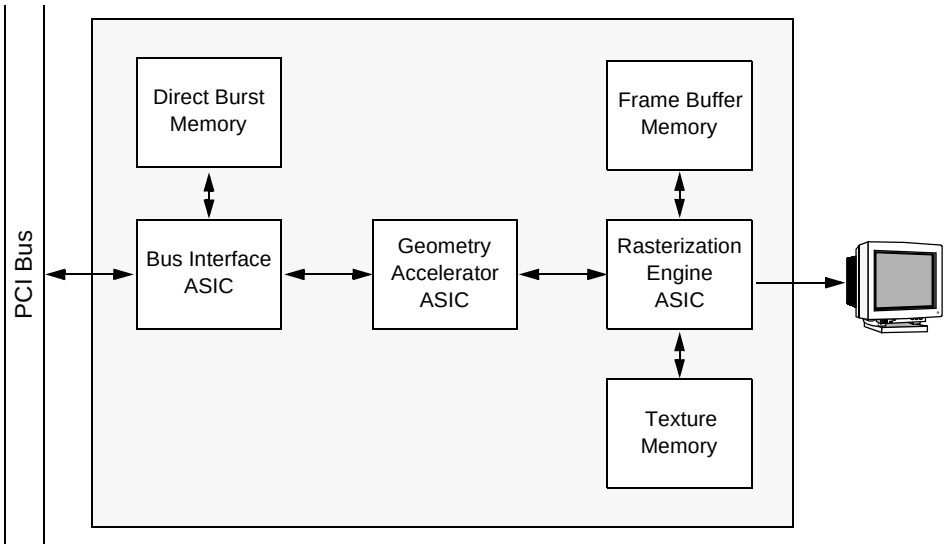

Figure 4-3 The Sun Expert3D high level architecture

- The *geometry accelerator ASIC* performs transform, clipping, and lighting
- The *rasterization engine ASIC* performs 2D and 3D rasterization, 2D and 3D texturing, pixel transfers, and fragment processing.
- The *texture memory* is 64 MB of SDRAM
- 64 MB of *frame buffer memory* is provided. The frame buffer memory is integrated with the rasterization engine and provides a high-resolution 10-bit RGB analog video output at dot rates up to 350 MHz.

Sun Expert3D-Lite Graphics

Sun Expert3D-Lite graphics is based on the Sun Expert3D graphics design — providing slightly lower 3D graphics performance and smaller dedicated texture memory — at a lower cost. Performance of Sun Expert3D-Lite graphics is similar to the Sun Elite3D m6 graphics accelerator accept that Sun Expert3D-Lite graphics provides hardware acceleration for texture mapping. Sun Expert3D-Lite graphics provides 16 MB of texture memory rather than 64 MB,

and 32 MB of frame buffer memory rather than the 64 MB provided by Sun Expert3D graphics. As a result Sun Expert3D-Lite graphics supports slightly lower screen resolutions:

- 1920 x 1080 maximum 2D resolution
- 960 x 680 @ 112 Hz stereo resolution

Sun XVR-1000 Graphics Accelerator

Sun XVR-1000 graphics introduces an entirely new graphics accelerator architecture with the MAJC graphics processor at its core. Sun plans to scale MAJC, along with a new rasterization engine (FBC3) and new 3DRAM64 frame buffer memory, to higher levels of performance and capabilities over time in new products. Sun XVR-1000 graphics is supported on Sun's Ultra 60, Ultra 80, Sun Blade 1000, and Sun Blade 2000 workstations.

This graphics board allows Sun to penetrate graphics-demanding technical markets including oil and gas, personal visualization, and design styling, providing Sun's UPA-based workstations with a competitive advantage with superior 3D performance, higher levels of quality, and new levels of flexibility. Sun XVR-1000 graphics is ideal for customer who require intensive texture mapping, high line quality, flexible high-quality output (DVI and S-video), or multi-monitor support.

Sun XVR-1000 graphics is the third-generation fast frame buffer graphics accelerator, designed for use in UltraSPARC processor-based systems. Sun XVR-1000 graphics provides Sun's most complete acceleration of OpenGL API to date, including 2D and 3D texture mapping, image processing, OpenGL 1.2, and a significant number of extensions beyond the OpenGL 1.2 API.

Feature	Specifications
Frame Buffer Memory	72 MB
Texture Memory	256 MB
Max. 2D Res. (30-bit color)	1920 x 1200 @ 75 Hz
Max. 3D Res. (30-bit color)	1920 x 1200 @ 75 Hz
Max. 3D Stereo Resolution	1280 x 1024 @ 112 Hz
Single-Pass Multisampling Capable	Yes
Dual Video Output	Yes

Table 4-5 Sun XVR-1000 graphics specifications

Key Features

Unlike 24-bit architectures, Sun XVR-1000 graphics, with its 30-bit (10-bit/channel) color support (38-bit RGBA), is capable of calculating and rendering 30-bit color to the screen. The result is over 16 billion possible colors for increased color accuracy and the elimination of color banding effects with high-definition imaging.

The 26-bit floating-point Z-buffer provides two advantages over traditional Z-buffers:

- It requires fewer bits/pixel compared to the fixed point format, 26 versus 32 bit, which reduces the Z-buffer memory requirements.
- It is far superior in resolving far away pixels. That is, a floating point Z gives things at the front of the scene more precision than those at the back.

The Sun XVR-1000 graphics accelerator also has the following key features:

- High-performance 2D and 3D graphics acceleration, including onboard geometry acceleration benchmarked at approximately than 20 M triangles per second
- Hardware-based, high-performance texture mapping (up to 163 MP/sec. texture fill rate) and dedicated texture storage
- Hardware-based, dedicated texture memory and frame buffer memory
- Superior quality 3D via single-pass multisampled antialiasing
- Super high resolutions supported in 2D and 3D up to HDTV resolutions, including 1920 x 1200 30-bit color, DB, 26-bit Z-buffered

Display Connections

The Sun XVR-1000 graphics accelerator has several video output connections available from each board:

- Standard 13W3 and HD15 analog outputs
- Analog S-video output for displaying graphics on a TV monitor or recorded to a VCR
- Dual display RGB support from a single frame buffer
- Digital DVI standard connector for driving digital flat panels and high-end projection systems

A standard VESA 8-pin mini-Din stereo connector that supports stereoscopic graphics video output in the standard Sun stereo resolutions is provided. It also supports the much higher stereo resolutions supported by the Sun 21-inch and 24-inch displays.

Display Resolutions

Sun XVR-1000 graphics video timings / monitor screen resolutions for the 13W3 connector are listed below.

Display Resolution	Vertical Refresh Rate	Sync Standard	Aspect Ratio	13W3	S-video	HD-13	DVI	Super-sampling
1920 x 1200	60d Hz	Sun	16:10	X		X	X	1
1920 x 1200	70, 75 Hz	Sun	16:10	X				1
1920 x 1080	60d Hz	Sun	16:9	X		X	X	1
1920 x 1080	72 Hz	Sun	16:9	X				1
1792 x 1344	60, 75 Hz	VESA	4:3	X				1
1600 x 1280	76 Hz	Sun	5:4	X				1
1600 x 1200	60d Hz	VESA	4:3	X		X	X	1
1600 x 1200	60, 73, 75 Hz	VESA	4:3	X				1
1600 x 1024	60 Hz			X				2
1600 x 1000	66, 76 Hz	Sun	16:10	X				2
1440 x 900	76 Hz	Sun	16:10	X		X	X	2
1280 x 1024	96, 108, 112 Hz	Sun-Stereo	5:4	X				2
1280 x 1024	60, 75, 85 Hz	VESA	5:4	X		X	X	2
1280 x 1024	67, 76 Hz	Sun	5:4	X		X	X	2
1280 x 800	112 Hz	Sun-Stereo	16:10	X		X		2
1280 x 800	76 Hz	Sun	16:10	X		X	X	3
1280 x 768	56 Hz	Sun	5:3	X		X	X	5
1152 x 900	120 Hz	Sun-Stereo	5:4	X		X		2
1152 x 900	66, 76 Hz	Sun	5:4	X		X	X	3
1024 x 800	84 Hz	Sun	4:3	X		X	X	4

Table 4-6 Sun XVR-1000 display resolutions

Display Resolution	Vertical Refresh Rate	Sync Standard	Aspect Ratio	13W3	S-video	HD-13	DVI	Super-sampling
1024 x 768	77 Hz	Sun	4:3	X		X	X	5
1024 x 768	60, 70, 75 Hz	VESA	4:3	X		X	X	5
960 x 680	108, 112 Hz	Sun-Stereo	14:10	X		X		6
800 x 600	75 Hz	VESA	4:3	X		X	X	8
768 x 575	50i Hz	PAL	PAL	X	X	X		10
640 x 480	180fsc Hz			X				16
640 x 480	60, 72, 75 Hz	VESA	4:3	X		X	X	16
640 x 480	60i Hz	NTSC	NTSC	X	X	X		16

Table 4-6 Sun XVR-1000 display resolutions

Note: All resolutions marked VESA use separate sync; the remainder use composite sync.

This graphics accelerator also provides programmable resolutions, which allows customers to define non-standard resolution output for specialty display output devices and projectors.

A single Sun XVR-1000 graphics board can drive two identical 21-inch displays up to 1280 x 1024 resolution. With two Sun XVR-1000 graphics boards in an Sun Blade 1000 or 2000 workstation, up to four displays can be driven up to 1280 x 1024 resolution in mono mode. If the display environment requires stereo graphics, three displays can be driven with the maximum resolution of 960 x 680 @112 Hz.

Note: To drive three displays at a 1280 x 1024 stereo resolution, three Sun Expert3D graphics cards in a Sun Enterprise 450 server is recommended.

To support the highest resolutions in wide-screen format, Sun XVR-1000 graphics uses up most of its on-board memory to drive these resolutions up to 1920 x 1200, 30-bit, double-buffered and 26-bit Z-buffered.

Other Important Graphics Technologies

Much of the success of graphics performance on Sun Blade 1000 and 2000 systems can be traced to advanced technologies and a high level of integration. Throughout the design of the Sun Blade 1000 and 2000 workstations, computational power is applied where it can best benefit graphics. Interconnects on many levels are designed to move graphical data quickly through the system. While each frame buffer or graphics accelerator relies on innovative engineering and sophisticated components to achieve high-performance, other components of the Sun Blade 1000 and 2000 workstations make critical contributions.

The UltraSPARC III and UltraSPARC III Cu Microprocessors

Until recently systems like the Sun Blade 1000 and 2000 workstations would have been impossible to build. Only with new advances in processor technology have CPUs been available with the necessary processing power to drive such a system. By using fast general purpose CPUs like the UltraSPARC III and UltraSPARC III Cu processors, it is finally possible to build inexpensive systems that provide high-end 3D performance.

In the graphics systems of the Sun Blade 1000 and 2000 workstations, much of the image processing is handled by the CPU, an approach with many advantages:

- *Better performance in memory-intensive tasks*

  When processing is done in the CPU, images can be held in system memory. Because many image processing algorithms operate on neighboring pixels, the system cache and MMU can help to dramatically speed up these functions.

- *Scalable performance*

  By giving image processing operations to the CPU, scalability can be achieved by adding faster or larger numbers of processors to the system. Many image processing functions can also benefit from parallel execution on multiprocessor machines.

- *Faster rendering*

  Most image processing is performed in a pipelined fashion with the results of one operation serving as the input image for another, with only the final image being displayed to the screen. With Sun's UltraSPARC III and UltraSPARC III Cu processor-based graphics systems, these intermediate images can be written to fast system memory. When the final image is ready, it can be cropped, panned, zoomed, and copied to the screen via a fast block copy.

- *Exploitation of the UltraSPARC III VIS instruction set*

  The UltraSPARC III VIS instruction set allows the CPU to directly access and operate on image (pixel) data with a high degree of parallelism. Other instructions are also available to format and move data at a high rate of speed. Still others can aid with volume rendering and video compression and decompression.

The Sun Fireplane Interconnect

Imaging, multimedia, and video applications all place large demands on system architectures. Furthermore, because 24-bit graphics is a standard feature on Sun Blade 1000 and 2000 systems, additional stress is placed on interconnect performance — three times the pixel data must travel through the system when dealing with 24-bit data rather than 8-bit data. Because most imaging and video operations are performed in the UltraSPARC III and UltraSPARC III Cu processors in most Sun graphics systems, a high-performance path is also needed for image data to move between the CPU, memory, and frame buffer.

The Sun Fireplane interconnect provides extremely high bandwidth to attached graphics accelerators with its 288-bit wide data path, and out-of-order signaling. The Sun Fireplane interconnect not only allows UltraSPARC III and UltraSPARC III Cu processors to issue a transaction on each clock cycle, but its 150-MHz clock rate enables it to deliver data to graphics accelerators at a very high rate of speed, keeping graphics pipelines full. Sun's scalable graphics systems benefit directly from higher system bandwidth whether they are located on the UPA64S interfaces or the PCI bus.

Performance

Sun's graphics systems have proven to be very effective at providing real-world performance in a wide range of applications that include windowing, 2D and 3D graphics, imaging and graphically intensive visualization. See Sun's Web page (http://www.sun.com) for additional details, including the results of key graphics benchmarks.

Software 5

Solaris Operating Environment

The Solaris 8 Operating Environment comes pre-installed on all Sun Blade 1000 and 2000 systems and contains the base-level functionality required for all Sun workstations. The Solaris 8 Operating Environment includes a proven, scalable 32- and 64-bit kernel, standards-based networking, and Java technology support. These technologies provide the foundation for building and deploying enterprise-class systems for multi-vendor, multi-client workgroup environments, as well as highly available data center environments. The strengths of the Solaris Operating Environment lie in its enterprise-class reliability, scalability, and performance.

The Solaris 8 Operating Environment is a 64-bit kernel that provides enhancements in overall performance, scalability, reliability, availability, security, and ease-of-use while maintaining backward compatibility for all existing 32-bit Solaris Operating Environment applications. The Solaris 8 Operating Environment continues the tradition of providing exceptional functionality and performance by delivering the following major enhancements:

- *Mainframe-class reliability, availability, and serviceability* for systems of all sizes
- *Higher performance*, the complete 64-bit computing environment provides greater capacity, precision, and performance
- *Enhanced scalability* with a 64-bit kernel that enables access to more system resources and the ability to consolidate applications onto a single server

- *Greater ease-of-use*, including Web-based installation, text and voice notes, and a graphical process manager
- *Comprehensive global support*, including support for the Euro currency symbol, complex text formats for Arabic, Thai, and Hebrew languages, and support for the development of multilingual applications
- *Software investment protection* with complete binary compatibility that allows today's 32-bit Solaris Operating Environment applications to continue to run on the Solaris 8 Operating Environment without modification
- *Extended security features* through authentication, data integrity, data privacy, and single sign-on capabilities so that tampering, snooping, and eavesdropping do not compromise data or associated transactions
- *32-bit and 64-bit development environment*, enabling developers to generate a single set of source code that runs on both operating modes

Designed to deliver the power, flexibility, availability, and compatibility to support enterprise-wide computing, the Solaris 8 Operating Environment combines four key computing elements — operating system, networking, window system, and user environment — into a stable, high-quality foundation that enables the development, delivery, and management of a wide range of computing solutions.

Operating System

Based on UNIX System V Version 4 (SVR4), Solaris 8 Operating Environment provides a rich applications development environment, and fully supports symmetric multiprocessing (SMP) and multithreaded applications on multiprocessor machines. The Solaris Operating Environment enables maximum portability across platforms by conforming to several important standards including SPARC ABI, CDE-compliant Motif, X11R6, POSIX 1003.1b and 1003.2, NIS, WebNFS™ software, HTTP, IIOP, UNIX 95 and UNIXþ98 branding, X/Open® (XPG4 base functionality), Energy Star, Kodak Color Management System™, and ISO 9660.

Networking

Sun's Open Network Computing (ONC+) provides transparent access to information and services distributed throughout the environment. Solaris also defines a standard interface to ONC+ for alternative networking technologies (DCE and NetWare) enabling smooth integration with enterprise computing

environments. Networking products such as NIS+, NFS, and RPC/XDR are supported for remote execution and data exchange. Transport layer independence provides support for a variety of network transport protocols such as TCP/IP (Figure 5-1).

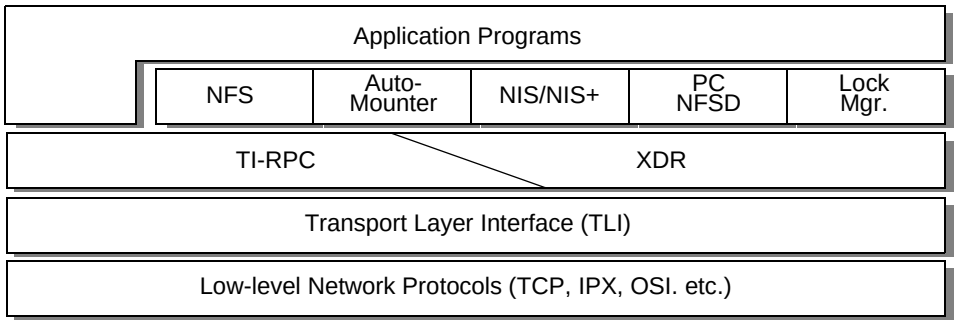

Figure 5-1 The Solaris Operating Environment supports a family of advanced networking protocols and services

Windowing Systems

The Solaris Operating Environment X11-based window server, user interface, and ToolTalk™ messaging services are engineered to exploit the Solaris Operating Environment distributed client-server computing model. To provide a consistent look and feel across all major UNIX platforms, Sun includes the Common Desktop Environment (CDE) with every copy of Solaris Operating Environment. Users and developers have the choice of continuing to use the Sun OpenWindows environment, or the Motif-based industry standard, CDE. The CDE environment includes graphics, imaging, audio and video services, and Display PostScript™ to facilitate the development and delivery of multimedia applications for communication and collaboration across the enterprise.

The Solaris 8 Operating Environment supports numerous graphics and windowing APIs such as Xlib, Display PostScript, and OpenGL to assist in the development of applications (Figure 5-2). In addition, the Solaris 8 Operating Environment includes Xlib and OpenGL 64-bit ready, high-performance graphic APIs.

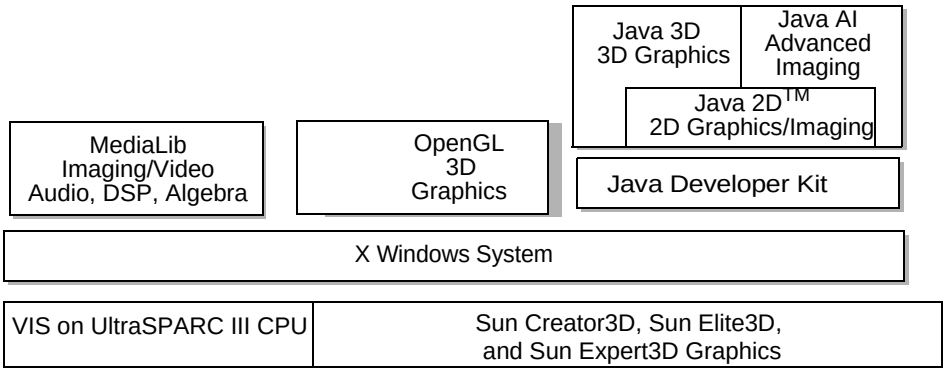

Figure 5-2 Solaris Operating Environment foundation graphics libraries and layered interfaces from Sun and other vendors

CDE has been extended to include a variety of tools to simplify the management of applications and the desktop environment — a front panel to launch applications with a single click; a workspace manager to create multiple virtual desktops, including support for multiple monitors; a style manager to personalize the use of colors, backdrops, mouse and keyboard behavior, and startup characteristics. Other tools include text and icon editors, an image viewer, process and system management controls, workgroup calendaring, file and print manager, web-browser, performance meter, and MIME-compatible electronic mail. Solaris Operating Environment CDE features drag-and-drop and cut-and-paste across OpenWindows and Motif applications.

Installation

Installation of the Solaris Operating Environment can be fully automated using the Solaris JumpStart™ software technology. When the system is first powered on, JumpStart software locates the install information over the network or from a local CD drive. The software installation is driven by profiles customized by the system administrator, or from a default installation profile, called the SmartStart™ profile. The SmartStart profile intelligently determines the best installation based on heuristics such as the amount of installed memory and available disk capacity.

Solaris Web Start software eliminates the UNIX system administration chores normally associated with software deployment through a flexible software management console that can be run from any desktop in an organization's

network. An easy to use tool for software deployment and management, Solaris Web Start software is a Java technology-based utility that simplifies and accelerates the installation of the operating system and associated software. A browser interface provides a familiar way to deploy and manage software resources in the workgroup and even across the Web. Customization and configuration options provide the flexibility needed for even the most unusual configurations, and by leveraging Sun's JumpStart technology, Solaris Web Start software provides the advanced replicated installation and remote software deployment features demanded by enterprise administrators:

- One-button and custom deployment options simplify installation and configuration.
- Java technology-based management console looks like a set of web pages.
- Support for a variety of media, including CD-ROMs and the Web, enhances distribution options.
- Extensive context-sensitive and on-line documentation delivers help and support when needed.
- File system tools streamline the software installation process.
- Replicated installation "profiles" ease the enterprise administration burden.
- Remote option directs deployment from any desktop to any host.
- A Software Developers Kit (SDK) extends the benefits of Solaris Web Start to all developers of Solaris applications.

Solaris Operating Environment Requirements

The Sun Blade 2000 workstation requires Solaris 8 (2/02) Operating Environment for operation. The Sun Blade 1000 workstation requires Solaris 8 (10/00) Operating Environment. Despite the fact that the Sun Blade 1000 is supported by version (10/00), several patches are needed for optimal performance (see below) should be installed. To support the UltraSPARC III Cu processors, the (10/01) version should be installed.

Note that neither of these systems run previous versions of Solaris (such as Solaris 7, 2.6, or 2.5). However these systems have binary compatibility with applications that run on those versions of the Solaris Operating Environment.

Recommended Solaris Patches for the Sun Blade 1000 Workstation

For optimal performance and reliability of Sun Blade 1000 systems, Update 6 (10/01) of the Solaris 8 Operating Environment or later is strongly recommended. If earlier versions of the Operating Environment are being used, we recommend that the following patches for the Sun Blade 1000 workstation be installed.

- 108528-09 or later
- 109882-04 or later
- 109888-05 or later (see Note 1)
- 110383-01 or later
- 110460-03 or later (see Note 2)
- 110723-02 or later
- 110800-01 or later
- 111228-01 or later
- 111292-03 or later
- 111293-03 or later

Note 1: Patch must be installed if Solaris 8 Update 3 (1/01) is installed. Solaris 8 Update 4 (4/01) or later does not require patch.

Note 2: Patch must be installed if Solaris 8 Update 2 (10/00) is installed. Solaris 8 update 3 (1/01) or later does not require patch.

Customers should consult a Sun Enterprise Field Service Representative about the appropriate Field Information Notice (FIN). The patches noted are the minimum level required for the Sun Blade 1000 platform. Customers should also periodically check for the latest available patch revisions on SunSolve. To check for the most up-to-date recommended patch matrix, it is necessary to refer to the FIN document.

Support for Graphics Accelerators

Sun Blade 1000 and 2000 systems support all of Sun's Solaris 8 Operating Environment graphics APIs, including the OpenGL and Java 3D libraries, Display PostScript, and the OpenWindows (X11-compliant) window system. Industry-standard X-extension libraries, such as Xlib and PEXlib, are also available and are accelerated via the Sun foundation graphics libraries.

As both imaging and geometry devices, the graphics products available for Sun Blade 1000 and 2000 systems accelerate many of the APIs mentioned above. The following sections briefly describe the foundation graphics interfaces and the functions accelerated by the Sun PGX64, Sun Creator3D, Sun Elite3D m6, Sun Expert3D-Lite, and Sun Expert3D graphics subsystems.

OpenGL

The OpenGL graphics application programming interface is an industry-standard, vendor-neutral software interface which operates independently of operating and window system platforms. Based upon its proprietary predecessor, GL, OpenGL is an applications programming interface that provides 2D and 3D graphics functions, including modeling, transformations, color, lighting, and smooth shading, as well as advanced features such as texture mapping, NURBS, fog, alpha blending, and motion blur. The OpenGL API works in both immediate and non-editable display-list graphics modes.

The OpenGL library is targeted at developers creating interactive 3D applications for the enterprise, the intranet, and the Internet. These developers are generally affiliated with technical markets or in research facilities. Potential users include those in computer-aided design and manufacturing, global information systems, simulation, industrial design and modeling, entertainment, biochemistry, and petroleum exploration.

Sun OpenGL for Solaris software provides a complete solution for developing and deploying interactive 3D applications across Sun workstations. It enables mainstream, industry-leading 3D graphics and visualization applications to be deployed on Sun Blade 1000 and 2000 systems at a compelling price / performance ratio.

The widespread multivendor availability of OpenGL libraries enable source code portability of 3D graphics clients. The Sun OpenGL 1.2.3 for Solaris API is a compliant implementation of OpenGL 1.2 from the OpenGL Architecture Review Board and is, therefore, source code compatible with other compliant OpenGL applications. Most existing OpenGL applications only need to be recompiled in order to run under the Sun OpenGL for Solaris API.

The Sun OpenGL 1.2.3 for Solaris API provides an implementation of OpenGL that incorporates hardware acceleration when used in conjunction with Sun Creator3D, Sun Elite3D, Sun Expert3D-Lite, and Sun Expert3D graphics:

- Transformations — 2D (3x2) and 3D (4x4)

- Geometry attributes — color, line type, fill pattern and textures, and so on
- Lighting and shading — flat and Gouraud as well as up to 32 light sources (positional, directional, spot, and ambient)
- Non-uniform rational B-splines (NURBS)
- Transparency — screen-door and alpha blended transparency
- Antialiasing
- Depth cueing — linear and scaled
- Texture mapping — 2D texturing of 3D surfaces (accelerated using VIS)

Specific OpenGL 1.2 extensions supported by Sun include:

- Texture level of detail control
- BGRA and packed pixel formats
- Texture specular color
- Texture edge clamping
- New interface imaging, and 3D texturing

Additional Sun-specific extensions include:

- Global alpha extension — allows applications to specify an alpha component that can be applied globally to all primitives (useful for cases in which many vertices share the same alpha value, because the application does not have to send an alpha component for each vertex).
- Vertex extension — allows applications to specify all vertex data (color, normal, coordinates, an so on) in a single function call (saves function calls overhead)
- Triangle list primitive — allows multiple triangle strips or fans to be specified within a single glBegin-glEnd pair (for improved performance).

Fully integrated with the Solaris 8 Operating Environment, Sun OpenGL 1.2.3 for Solaris allows developers to take advantage of it's advanced features, including multithreading and full support for 64-bit computing. Sun OpenGL 1.2.3 for Solaris also includes new imaging extensions to allow developers access to both graphics and imaging functionality within the same application and other enhancements to support increased performance and functionality. The Sun OpenGL for Solaris API can run with Common Desktop Environments (CDE) or OpenWindows environments. A defined common extension to the X Window System allows OpenGL client to run across distributed heterogeneous networks.

More information about Sun OpenGL 1.2.3 for Solaris can be found at: http://www.sun.com/software/graphics/OpenGl;

Java 3D Application Programming Interface

The Java 3D API is an application programming interface used for writing stand-alone three-dimensional graphics applications or Web-based 3D applets. Java 3D API gives developers high level constructs for creating and manipulating 3D geometry and tools for constructing the structures used in rendering that geometry. With Java 3D constructs, application developers can describe very large virtual worlds, which, in turn, are efficiently rendered by Java 3D API implementations.

The Java 3D API specification is the result of a joint collaboration between Silicon Graphics, Inc., Intel Corporation, Apple Computer, Inc., and Sun Microsystems, Inc. All had advanced, retained mode APIs under active internal development, and were looking at developing a single, compatible, cross-platform API based on Java technology.

The Java 3D API draws its ideas from the considerable expertise of the participating companies, from existing graphics APIs, and from new technologies. Java 3D API's low-level graphics constructs synthesize the best ideas found in low-level APIs such as Direct3D, OpenGL, XGL and QuickDraw3D. Similarly, Java 3D API's higher-level constructs leverage the best ideas found in several modern scene graph-based systems. Java 3D API also introduces some concepts not commonly considered part of the graphics environment, such as 3D spatial sound to provide a more immersive experience for the user.

Java 3D API provides a host of capabilities that yield a high degree of interactivity while preserving true platform independence, including:

- High-performance
- Rich set of 3D features
- High-level, object-oriented paradigm
- Wide variety of file formats, including vendor-specific CAD formats, interchange formats, VRML 1.0, and VRML 2.0
- 3D view model, enabling images to be rendered on a wide variety of display devices
- High-performance vector math library for advanced object classes
- Rendering models and modes

- Sound and MIDI support
- Geometry compression, enabling geometry to be represented in an order of magnitude less space than most traditional 3D representations, with very little loss in object quality

Java Advanced Imaging API

Image processing techniques are used for manipulating and displaying images. Examples of image-processing techniques range from simple operations such as contrast enhancement, cropping, and scaling to more complex operations such as advanced geometric warping and frequency domain processing.

These are used in a variety of applications including:

- Astronomy
- Medical imaging
- Geospatial data processing
- Defense and intelligence
- Photography
- eCommerce and retail

The Java Advanced Imaging API broadens the reach of the Java platform to allow sophisticated, high performance image processing functionality to be incorporated into Java applets and applications.

The Java Advanced Imaging API goes beyond the functionality of traditional imaging APIs to provide a high-performance, platform-independent and extensible image processing framework.

For more information see `http://java.sun.com/products/java-media/jai`.

Software Development Support

Forte Developer Software Products

Successful application development requires that programmers have high-performance compilers and tools. The Sun Forte Developer software suite includes highly optimizing, automatically parallelizing compilers (versions of

Forte Developer software are available that support the Fortran, C, and C++ programming languages); libraries of highly optimized routines; and tools to help analyze and tune code for additional runtime performance.

Forte Developer software features include:

- Integrated programming environment
- Motif user interface, providing a standard look and feel
- Tight, editor-centric tool integration
- Hyperlinks, enabling easy tool navigation
- Multiprocessing, multithreaded development tools
- Distributed and parallel make utilities
- Incremental linker, for faster builds
- Fix and Continue, enabling defects to be found and fixed quickly
- AppGuru, enabling very fast application development for C++
- New version of Rogue Wave Tools.h++ 7.0 class library
- Motif, Windows, and Java GUI Builder, for cross-platform development
- WorkShop Visual, enabling quick and easy GUI development
- GUI capture and testing, providing reverse engineering capabilities
- Three dimensional data visualizer, speeding debugging of complex arrays
- WorkSets and PickLists, facilitating quick access to work sessions
- WorkShop TeamWare, for source code and configuration management
- Extensive on-line manuals and help system

Of particular interest to developers is the ability of Forte Developer software products to perform several advanced optimizations that can speed applications performance:

- *Instruction scheduling*, to arrange the order in which instructions are executed and make optimal use of available machine resources.
- *Profile feedback*, to obtain frequency information about a program. The program is executed and the frequency information is applied to optimizations such as code motion and inlining.
- *Loop parallelization*, to rearrange loop code so that multiple processors may be work in parallel to complete the loop.
- *Cache blocking*, to rearrange loop code to make maximum use of the processor cache.

- *Loop inversion*, to reverse the order of nested loops to gain the advantages of improved loop parallelization or better cache blocking.

To take advantage of innovative UltraSPARC III and UltraSPARC III Cu processor features, Sun Forte Developer software compilers support both traditional and hybrid versions of the SPARC Version 9 architecture. Full 64-bit computing is available with SPARC V9 support. A hybrid version, called V8+, precludes the use of all V9 64-bit addressing instructions, ensuring 32-bit compatibility with existing versions of the Solaris Operating Environment and with other existing applications, while still allowing access to most of UltraSPARC III and UltraSPARC III Cu processors' advanced capabilities, including the VIS instruction set.

Java Application Development

A discussion of software development would not be complete without mentioning Java technology. Taking the industry by storm, the Java programing language promises true platform-independent software development for a large number of applications. Software developers have instantly recognized the potential of Java applications, with thousands of firms currently developing, or planning to develop Java technology-based products. Sun, the original developer of the Java programming language offers software developers a unique opportunity with a comprehensive product line designed to streamline development.

The object-oriented Java platform delivers the benefits of reusable code, reduced cost of ownership, and broad integration, with the complex, heavyweight object housekeeping process required by other object-oriented development models. Sun's family of Java APIs and development products, including Java WorkShop™ software, the Java 2 SDK, and Java Studio™ software, empower developers to create an entire new class of applications that truly provide network-based computing. Sun Blade 1000 and 2000 workstations are ideal platforms for these tools, permitting the development of both client and server components of Java technology solutions. Products can then be easily deployed to more powerful Sun Java Web Server™ technology.

The Java 2 Software Development Kit is bundled with the Solaris 8 Operating Environment. The Java 2 SDK provides both essential development tools required for creating Java applications and a high-performance, scalable runtime environment that reliably delivers the faster execution of Java applications. Designed to deliver superior performance and scalability across

the enterprise, applications developers recognize that the runtime system in Java 2 for Solaris sets a new standard for Java technology performance and reliability.

Open Firmware

The Sun Blade 1000 and 2000 workstations support the use of a standardized PROM-resident monitor program that is written in a special threaded-interpretive language. Called Open Firmware, this monitor is conformant to the IEEE 1275-1994 standard, also known as Standard for Boot (Initialization Configuration) Firmware. Open Firmware can be brought up during the power-on process if a problem is encountered, or by executing a system *shutdown* followed by a level 0 *init*.

Once the Open Firmware monitor has control, a variety of diagnostics are available for key subsystems and peripherals:

- Video graphics
- SCSI interface logic on the system board
- Ethernet interface and AUI
- Internal and external disk drives
- Tape, diskette, and CD-ROM drives
- Serial ports
- Keyboard
- Memory

The Open Firmware monitor also provides tools to allow the continuous monitoring of the network and selective probing of devices on the SCSI bus.

Boot-time behavior and some diagnostics in Sun Blade 1000 and 2000 systems are controlled through 1 MB of flash PROM. The use of flash PROMs permit the reprogramming of specific code blocks to implement updates and enhancements without requiring physical access to the PROMs. Reprogramming may be done from a CD-ROM located in the system or remotely by a system administrator over a local area network.

Diagnostics

The Sun Blade 1000 and 2000 workstations are designed for easy diagnosis and problem repair. Supporting this are several PROM-resident and UNIX platform-based diagnostic programs that can be applied by end users and service personnel.

Power-On Self-Test (POST)

Under user control, a power-on self-test (POST) can be automatically executed to test the system board, on-board I/O devices, and memory system each time power is applied to the system. While not intended to be a comprehensive diagnostic, POST can quickly establish that no severe problems exist with the system, and communicates that through a set of light-emitting diodes (LEDs) on the keyboard. POST tests may be monitored via a serial-port connection to another desktop system or dumb terminal.

SunVTS

The SunVTS system exerciser is a graphically oriented UNIX application that permits the continuous exercising of system resources and internal and external peripheral equipment. Used to determine if the system is functioning properly, SunVTS incorporates a multi-functional stress test of the system through operating system level calls, and allows the addition of new tests as they become available.

References

Sun Microsystems posts product information in the form of data sheets, specifications, and white papers on its Internet World Wide Web page at: *http://www.sun.com*.

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